Effects of El Niño Southern Oscillation on Food Prices, Dietary and Nutrient Intake among children: Case Study in Iquitos, Peru

By

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Abstract

El Niño Southern Oscillation (ENSO) is a naturally occurring atmospheric phenomenon that leads to inter-annual shifts in precipitation, temperature, and river discharge in Peru. More recently, there is evidence to suggest that ENSO is evolving in response to Global Climate Change. Very little research has been conducted on how ENSO affects food prices, dietary intake, and overall nutritional security. The major objectives of this thesis are to explore the relationship of ENSO and: (1) river discharge, (2) food prices, (3) frequency of meal patterns, (4) amount of food consumed, (5) Dietary Diversity (DD), (6) macronutrient and micronutrient intake, and (7) nutrient adequacy among children 9-36 months of age in the Peruvian Amazon.

Data on monthly ENSO indices were extracted from National Oceanic and Atmospheric Administration (1969 to 2015). Daily river data was retrieved from the Sedaloreto water treatment plant (1969 to 2015) in Iquitos, Peru. Data on weekly food prices were obtained from Peruvian Ministry of Agriculture and Irrigation (2008 to 2015). Data on monthly dietary intake were obtained from The Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development birth cohort study in Iquitos, Peru (2010 to 2014).

Using regression models, Multivariate ENSO index (MEI) was identified as the best fit for associations with river discharge levels, in comparison to other ENSO indices. In addition, severe categories of MEI were also strongly associated with river flows. Using time series regression, ENSO severity, river level and seasonality were associated with local food prices, particularly yucca, eggs and sugar.

Results from longitudinal poisson, negative binomial, and regression models show that under moderate El Niño & La Niña, and strong La Niña, there were reduction in the number of meals with fish, grains, plantain, dairy, sugar and rice. In strong La Niña, reduction of rice and grains were 18-20%, and interestingly, there is a higher intake of plantains by 99% suggesting possible substitutions. The practice of consuming gifted foods is higher during moderate El Niño and weak La Niña and is higher among girls compared to boys. Despite seasonal availability, DD remained consistent, however under La Niña conditions, girl's DD score is reduced significantly compared to boys.

Energy intake was significantly lower under moderate El Niño and significantly higher during weak La Niña. Girls consumed 89-112 less calories than boys even after adjusting for weight and other covariates, particularly under moderate La Niña. Further, gender differences were found in animal source protein intake, iron, zinc, calcium intake under various ENSO conditions. Overall, there was high prevalence of inadequacy for vitamin A (among the non-breastfed group), calcium, iron, folate, and zinc. Nutrient Adequacy Ratios of calcium, iron, and zinc were negatively associated with weak, and strong La Niña.

This is the first study to show ENSO associations with local ecological factors, regional food prices and dietary intake in the same setting and time frame. These findings illustrate that ENSO, a large scale atmospheric phenomenon, is linked with individual-level dietary intake. The findings also highlight the gender differences in dietary intake observed under various ENSO conditions. Further studies are needed to explore how dietary patterns in other ENSO-affected regions (South East Asia, Southern China, Zimbabwe, Ethiopia) are altered. Peruvian national nutritional programs should strongly consider using ENSO indices as a factor in determining the distribution of additional food and cash subsidies to the most vulnerable households, and especially, to such households with girls.

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Chapter 1 : Introduction

The impact of climate change on dietary intake and child nutritional status is unknown. Currently, under nutrition contributes to 35% of the disease burden in children less than five years of age, and is mediated through suboptimal breastfeeding, morbidity and insufficient energy and nutrient intake (Black et al. 2008). This estimate is expected to increase with more frequent crop failures, rising food prices, extreme weather events such as flooding & hurricanes, as a result of climate variability (Kovats 2000). Questions remain on how much, to what extent, and through which pathways climate variability affects nutritional status in local communities.

There is a growing body of literature that suggests that the rise in El Niño Southern Oscillation (ENSO) frequency and intensity is coupled with climate change processes, i.e., a rise in global temperature associated with increased ENSO frequency (Cai et al. 2014; Change 2014). Globally, ENSO events and other climate variability have direct effects on food prices depending upon the intensity of the events, and these consequently affect food consumption patterns (i.e., reductions in fish, dairy, meat, and vegetable intakes) and nutrient intakes (energy, carbohydrates, protein, vitamin A, C, folate, B12, iron, zinc, calcium). In the Peruvian Amazon, annual river discharge shows a coupling pattern with the ENSO cycles - there is a lower river level during the El Niño phase coupled with low rainfall, and a higher discharge during the wetter La Niña phase (Schöngart and Junk 2007; Lavado-Casimiro et al. 2013). Disturbances in seasonal river flow affect the flood pulse behavior with implications for the life cycles of terrestrial and aquatic ecosystems, and crop productivity (Junk et al. 2007). This consequently affects both livelihood and dietary intakes in the region. To date, there are no published systematic studies examining the effects of non-linear ENSO events on food prices in Peru, or how weather and economic shocks affect dietary intake and ultimately, the nutrient intakes of children in the Peruvian Amazon.

This study was designed to examine the impact of large-scale processes, ENSO, on individual dietary intake in a vulnerable population, and to quantify the mediating pathways such as food prices. This study was conducted as part of a longitudinal birth cohort in Iquitos, Peru, where river discharge plays a large role in seasonal availability of foods; Therefore, I am able to explore long term trends and within individual intake over a period of time.

The dissertation begins with the literature review of the consequences of climate change on human health and in particular, in the study area. More specifically, the background focuses on the mediating pathways through which climate change affects dietary intake followed by methods, population, livelihood, environment, and ecology of the study setting. Chapters 3-5 follow it, addressing sequentially the aims of the study. Finally, chapter 6 outlines the findings along with the discussion of strengths and limitations of the overall study and implications for policy and programs and future research.

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Chapter 2 : Background, Settings & Methods

Rationale

Climate change refers to a sustained change in the temperatures that occur on a larger time scale such as decades or more in comparison to day-to-day variability seen in weather patterns (Kovats 2000). The potential impact of climate change on human health occurs through many mediating pathways that have both short-term and long-term consequences. The predicted increases in temperature range from 1.4 to 5.8º Celsius globally for the next 50 years, and the severity of the effects of this warming vary widely across different regions of the world. There are direct and acute effects such as flooding, hurricanes, and heat waves leading to high mortality and morbidity among human populations. There are long-term ramifications such as crop failures, food insecurity and increased geographic distribution of infectious disease agents such as mosquitoes, sand flies, tsetse flies, and ticks due to cumulative changes in the physical environment. These processes are caused and amplified by globalization, the demographic transition, urbanization, population growth, land use / land cover changes, and depletion of natural resource (IPCC, 2013).

There is a growing body of literature that suggests that the rise in El Niño Southern Oscillation (ENSO) frequency and intensity is coupled with climate change processes, i.e., a rise in global temperature is associated with increased ENSO frequency (Cai et al. 2014). ENSO is a naturally occurring oceanic-atmospheric interaction that occurs in the Pacific, which leads to profound weather conditions around the world by drastically affecting temperature and precipitation patterns. This happens in two phases (El Niño and La Niña) over 2-7 year cycles. During the El Niño phase, global mean temperatures are higher and vice versa in the La Niña phase. ENSO events are associated with droughts in SE Asia and in southern Africa, floods in the Amazonian regions, and hurricanes in the Carribean and in the Gulf of Mexico. They have also been associated with an increased incidence of cholera in India, Bangladesh, and Peru (Ramírez, Grady, and Glantz 2013; 2000a). In addition, ENSO events affect the ecology of vector-borne pathogens. Studies have found increased incidences of malaria and dengue in Colombia, Peru, Venzuela, India, Sri Lanka, Indonesia and the Pacific Islands as a result of changing vector ecology. Figure 2-1 illustrates various areas that are affected by El Niño in terms of drought, flooding, and changing vector ecology (Kovats et al. 2003).

Though there may not be discrimination in the distribution of these events globally, vulnerable populations are at a heightened risk for disease burden. The heat waves that result from El Niño (and other causal factors) disproportionally affect children and the elderly. Crop failures and reductions in fisheries are projected to occur in regions where the population is highly dependent on agriculture and fishing as a primary source of livelihood (McMichael, Woodruff, and Hales 2006). Experts speculate that periods of high food prices caused by crop failures have slowed efforts to reduce undernutrition, particularly micronutrient deficiencies in developing countries (Timmer 2010).

Climate Change & Seasonality

There are three primary drivers of seasons in the Peruvian Amazon – ENSO, deforestation and more importantly sea surface temperature in the Atlantic Ocean (Malhi et al. 2008; Espinoza Villar et al. 2009). Current data from this region suggests there is more inter annual differences than seasonal differences, likely due to the (Espinoza Villar et al. 2009) strong signals from ENSO that occur every 2-7 year. The major projected changes in the rainfall patterns in the Amazon occur in the dry season (June to November), where the there have been increasingly drier patterns since the 1970s, which is further compounded by deforestation (Malhi et al. 2008). Although rainfall patterns in the Peruvian amazon has been studied in the context of decadal and inters annual trends – there are no studies to identify the timing of the seasonal dry and rainy periods. A recent study done in the Brazilian Amazon (bordering the location of city of Iquitos) illustrated that timing of the seasons is affected by Atlantic sea surface temperature, and more importantly these caused shifts in the time between dry to wet season (Liebmann and Marengo 2001). One of the larger, practical implications of these rainfall shifts is the impact on crop productivity. It will be important to tease apart the impact of the seasonal, and the long trend that occurs due to natural variation and those related to climate change.

Climate change and crop productivity

It has been estimated that 1.5- 2 º C increase in temperature, especially during the dry season, from 1975 to 2009 in Nepal had lead to decreased rainfall and delayed monsoon season in some areas while increasing rainfall and intensity in other areas (Krishnamurthy et al. 2013). Productivity of crops such as wheat and barley, which are highly correlated with the seasonal rainfall level were affected vastly due to the shift in seasons (Krishnamurthy et al. 2013). Authors speculate that decrease in the length of monsoon season or the delay in the initiation of monsoons can lead to loss in crop yield (Krishnamurthy et al. 2013). Temperature increase leads to loss of soil moisture content and crops that are rely heavily on the optimum soil moisture are affected by the change in temperature. Researchers in Nepal have found that temperature had negative correlation with wheat, barley, potatoes and rice while positive correlation with maize and millet, which are considered to be drought resistant (Krishnamurthy et al. 2013). Based on the twenty General Circulation Models (GCMs) on temperature and precipitation trends observed in Latin America now, projections were made for crop productivity in 2030s. Essentially, crop yield is expected to have 10% decrease in wheat and rice (Brown and Funk 2008). Although globally, GCMs on climate change on agricultural productivity is estimated to positive due to increase in temperature in mid latitudes, it should also be noted that many of the of the developing countries are located near the equator where projected climate change on crop productivity are varied and overall, negative (Lobell et al. 2008; Lee 2009). Projected links between projected climate changes in next decade grouped by eighteen agro-ecological regions of the world (boreal, temperate, and equatorial regions further classified by soil type, pH, precipitation, topography) produced a similar trend where crop yield is higher in the developed countries (OECD) compared to negative yield in rest of the world (Lee 2009). According to the projected crop yield in 2020 (after controlling for GDP and population growth), most of crop productivity declines take place in the developing countries that are located in the tropical area (Lee 2009). The decrease in rice and wheat productivity and output is particularly alarming. The increased crop yield observed in the Asia regions are due to the rise in arable land in Russia because temperature increase will equate to increase in arable land in the mid latitudes (Lee 2009).

ENSO Effects on Crop Productivity and Food Prices

Weather is an integral determinant of crop productivity (Ubilava 2014). Crop productivity is contingent on many environmental factors including rainfall intensity, seasonal shifts, soil moisture and temperature. For example, wheat and barley productivity are highly correlated with seasonal rainfall level and are directly affected by the shift in seasons (Krishnamurthy et al. 2013). In addition, a decrease in the length of the rainy season or a delay in the initiation of the rainy season can also lead to losses in crop yield

(Krishnamurthy et al. 2013). Another pathway of crop loss is through temperature change, because a small rise in ambient temperature can lower soil moisture content, thus lowering crop yields.

Studies have found that ENSO events explained 33-40% of the variance of interannual rice production in Indonesia, 57% of the variability in corn production in Zimbabwe, and 7-25% of the variability in tobacco, peanut, soybean and corn yeilds in Southeastern United States (Naylor et al. 2001; Hansen, Hodges, and Jones 1998). The variability associated in crop yields are in different directions depending upon the phase of the ENSO (El Niño vs La Niña) and have differential effects across various regions of the world. For example, the El Niño phase can cause torrential rainfall in regions of Latin America causing crop failure through excess soil saturation and mudslides, while in South East Asia, Malaysia, and Indonesia crop failures occur through reduced rainfall, and drought-like conditions.

Due to variable crop production during ENSO events, many studies have posited and quantified the direct link between ENSO, the economy and food prices (Ubilava 2014; Hansen, Jones, and Kiker 1999). The current literature shows a wide range of methodologies used to examine these links, and the measurable effects vary by geographic location and the intensity of the ENSO events. A study that used a principal component analysis approach to normalize price and ENSO index found a cross correlation lag of 0.90 with soybean prices, whereby future soybean prices for up to 2 years could be predicted by the ENSO index (Keppene 1995). Another econometric study by Brunner using Granger-causality models and identified that ENSO events had the greatest impact on world cereal prices, followed by beverages and other non-oil agricultural products (Brunner 2002). These models examine the time series of sea surface temperature (SST) anomalies and food commodity prices, where ENSO “surprise” elements are characterized as trends of ENSO spikes correlating highly with price hikes even after controlling for within-variable lags in exposure and outcome variables. Then over a period of time, ENSO surprise elements are examined to see if price hikes track them. In this Granger-causality model, it was estimated that 20% of the variability in global food commodity prices are explained by ENSO “surprise” events (Brunner 2002).

However, in another study examining ENSO events on Gross Domestic Product (GDP) growth and commodity prices among 22 countries using the same approach as Brunner et al (2006), non-significant results were found in Peru and Chile with GDP (Laosuthi and Selover 2007). Although, these are contradictory findings, the null results could be attributed to the size of economy, safety nets provided by the government, proportion of agriculture and fisheries contributing to the economy, and crop varieties. This same study also found significant rice and maize price increase associated with ENSO – these analysis were not done within country, and this study used quarterly data where some of their ENSO effects might have attenuated (Laosuthi and Selover 2007). More recent studies emphasized the importance of characterizing the non-linearity of ENSO events with food prices and in addition, focusing on the differential effects by phases of ENSO and to model the phenomenon more appropriately. Ubilava et al showed that the El Niño phase was associated with 3% decrease in world wheat prices, whereas La Niña was associated with 5-7% price increase in Canada, US, Europe and Argentina (Ubilava 2014). Further, the author suggests that autocorrelations between the two phases of ENSO have lead to stark differences, in parallel with climatology research warranting more attention and care to model the El Niño and the La Niña components separately (Ubilava and Holt 2013; Ubilava

2014). In parallel, food price hikes also show non-linear movement due to the dynamics of supply-demand, storage behavior, and market transmission (Pede, Valera, and Alam 2013).

Ubilava describes multiple pathways through which global wheat prices are affected by ENSO, from both supply and demand perspectives. Crop failures would be considered "direct supply" impacts whereas impediments to transportation during the delivery of cereals to the market would be considered "indirect supply" effects. From the demand perspective, countries that were previously self-reliant for crops may import grains during ENSO years, when there is crop damage (Ubilava 2014). Many of these effects are evident after an ENSO event, particularly in Latin American countries that are directly affected by it.

Food Security in Peru

According to the 1996 World Food Summit, food security defines the capacity of household to have "access to safe and nutritious food at all times, while still meeting dietary needs and preferences" (Jones et al. 2013). The concept of food security first evolved during the later period of World War 2 to assess the nutritional needs of the population and in 1970s, food security was associated with the food supply, especially during the volatile time of food crisis and political disorder (Jones et al. 2013). In the 1980s, this concept morphed into physical and economic access and availability of food, when researchers identified inadequate access despite food sufficiency and production at a national level. In the 1990s, due to the shift in nutritional research on micronutrient deficiency, the food security concept focused on quality in addition to quantity.

Food insecurity tool is used in routine nutritional surveillance in assessing population nutritional status, for example, in examining the impact of agricultural policies or trade agreements on food systems. More importantly, in disaster response situations to identify households that requires immediate food aid and other interventions. Furthermore, it is not only limited to developing country settings, as it has been found to be associated with obesity & illness in studies conducted in the US. Food security status can be chronic in situations where strong seasonal factors dominate the food systems (Jones et al. 2013). Food insecurity is associated with morbidity (malaria, HIV, diabetes), poor infant feeding practices, micronutrient status, dietary diversity & quality, mother's depression, and children's cognitive function, social skills and academic performance (Skalicky et al. 2005; 2005; Hadley and Patil 2006; Seligman et al. 2007; Hadley and Patil 2008; Perez-Escamilla et al. 2009; Bernal et al. 2012; Nanama and Frongillo 2012; Jyoti et al. 2005; Melgar-Quinonez et al. 2006; Kirkpatrick et al. 2008).

In the last decade, Peru has achieved large milestones regarding food security status and nutritional status of underserved population (OECD 2016). These achievements however vary widely within Peruvian provinces. For example, Huancavelica and Cajamarca have 50% poverty levels and third of the children under five suffer from chronic under nutrition. As one would expect, these two provinces also rank high on the vulnerability to food insecurity. Figure 2-2 shows the ranking of these provinces within Peru by vulnerability to food insecurity by poverty levels. Loreto province where this study is nested, is ranked 11th (among 25 provinces) for vulnerability to food insecurity. There are several national programs and policies in place to decrease food insecurity experience in these regions (OECD 2016). These include multi sectoral strategies to reduce poverty and improve agricultural productivity, conditional cash transfer programs to qualified poor households, and supplementary food based program targeting children under seven years of age (OECD 2016). These programs do not yet include strategies to ameliorate food insecurity under natural disasters.

ENSO in Peru

In Peru, the effects of ENSO have been well known due to the consecutive damage endured during each cycle since the 1950s. Large scale damages to the fishing industry during the 1972 El Niño, lead to a nationalization of the fishing industry. The ENSO event that occurred in 1982-83 led to crop failures and soaring food prices (Caviedes 1985). During the ENSO even that occurred in 1997-98, there were widespread crop loss due to excessive rain in the coastal regions of Peru (Bayer et al. 2014). Loss was felt in the livestock and fisheries sectors that could have reduced overall animal source protein intake. Further compounding the catastrophe were the damages incurred in transportation infrastructure, which dramatically reduced access to food markets (Danysh et al. 2014).

Economic Shocks, dietary intake and micronutrient adequacy

With higher food prices, the proportion of dietary intake from various food groups is reduced leading to a less diverse, lower quality and even smaller quantity of consumed food (Bouis et al. 2011). In Peru, half of the households were consuming below the required energy adequacy (2525 calories) before the 2007-2008 price hikes, and after this period, there was an additional 7% of the households that became below adequate (Iannotti and Robles 2011). This effect was more pronounced among the lowest wealth quintiles households located in the urban areas (Iannotti et al. 2012).

Figure 3 qualitatively illustrates the amount of household expenditure for various types of food before and after the price rise. In low income settings where household spend up to 50-80% of the income towards food expenditure, the share of expenditures after price hikes is stark and dramatically reduces the quality of dietary intake – i.e. reduction in vegetables and animal source proteins, which are rich sources of micronutrients (Brinkman et al. 2009). Country level studies undertaken in Bangladesh, Kenya and Philippines have illustrated the same pattern where decreasing income quartiles within a country experienced the greatest reduction in micronutrients intake is lower compared to the reduction in energy intake after a price hike (Bouis et al. 2011). This is quantified and defined as price elasticity where the quantity of food consumed changes in response to change in price of the food. Staples in Bangladesh (particularly rice), for example, have a coefficient of -0.2, which is interpreted as 20% reduction of rice consumption with 1% increase in the price of rise (Bouis et al. 2011).

In contrast, the elasticity for non-staples is usually higher with an average coefficient of -0.27. Price elasticity of food is always expected to have an inverse relationship due to the basic principles of supply and demand. In addition, the relationship between the price of staples and non-staples plays a role in dietary quality as seen in figure 2-3. This is known as the cross price elasticity, where a change in the price of one food affects the expenditure allocated to other food groups (Bouis et al. 2011; Green et al. 2013). A recent global meta-analysis of 136 studies across 162 countries found that in low income countries, animal source protein (meat, fish and dairy products) is reduced to the highest degree when there is a 1% increase in price compared to cereals, fats and oils (Bouis et al. 2011; Green et al. 2013). Similarly, a national study in Guatemala illustrated the same price-food group relationship with animal source foods (ASF) but also found similar effects for legumes (Iannotti et al. 2012). In particular, vitamin B-12 and folate had the highest food-price elasticites but prevalence of inadequacy also increased for zinc, iron, and vitamin A after food price increases (Iannotti et al. 2012). ASF is the only source of vitamin B-12, hence any reduction in ASF leads to directly to anemia, weight loss and in extreme causes, neuropathy (Allen 2003; Murphy and Allen 2003). This has large implications for children, particularly for their long-term growth and development. A national level study in Indonesia (another geographic location that is affected by ENSO events) demonstrated that reduction of household expenditure on animal source protein after a food price crisis leads to greater odds of stunting among children under five years of age (Sari et al. 2009).

As mentioned previously, in Peru, there have been media reports on price hikes subsequent to every strong ENSO events. To this date, there has not been a single systematic study examining the effects of ENSO on food prices and consequently on dietary quality among children in Peru (or elsewhere). The first aim of the proposed study is to examine the relationship between non-linear ENSO events on rice prices as it contributes to 21% of Peruvian total energy intake. The second aim of the study will focus dietary intake among children in a low resource setting in the Peruvian Amazon. In the next section, climatological and ecological factors affecting dietary intake in the Peruvian Amazon are explored in detail.

ENSO and River Discharge in the Amazon

The Amazon is an important feature of earth's system as it performs multiple functions as an energy sink, biodiversity preserve (~25% of species richness globally), and a provider of transpiration services (~15% globally) (Malhi et al. 2008; Laurance and Williamson 2001). There are multiple natural drivers of climate variability in the Amazon that have both chronic and acute impacts on river discharge and consequently, livelihood.

ENSO is a naturally occurring phenomenon that results from the changes in the interaction of ocean and atmosphere due to differences in the temperature gradient. Under normal conditions, warmer SST rises and this moves westward with moisture caused by the SST gradient. Under El Niño conditions, SST is warmer -- thus weakening the circulation of moisture -- and as a result precipitation occurs in the ocean with dry land conditions in Peru. According to the fifth 2013 IPCC report (Section 12.4.4), there is high confidence that rainfall variability due to ENSO is expected to rise with ENSO magnitude. The report identified regions with reduced rainfall in the dry season (including eastern Amazonia, Northeast and Eastern Brazil) and regions with increased rainfall during the wet season. It is also predicted with high confidence that the frequency of extreme precipitation events such as flooding will increase due to these changes.

In South America, much of the moisture circulation is driven by the north east winds from the Atlantic interacting with the Andes mountain on the west coast along with the tropical cyclone activities associated with intertropical convergence zone (Marengo and Hasternath 1993; Liebmann and Marengo 2001; Marengo et al. 2013b). On an annual basis, these factors together create the South American Monsoon system. Some scientists have posited that evapotranspiration is the key element in driving these seasonal shifts in precipitation (Lindsey 2007). Because South American continent has distinct topography, there are multitudes of interaction and feedbacks between land, ocean, forests and mountains that affect moisture circulation. Thus, the effects of ENSO on precipitation and river discharge varies by these micro climates.

There are four primary pathways through which ENSO affects river discharge – precipitation, temperature (evapo-transpiration is grouped with this due to the association of temperature with vegetation index), runoff and snow melt, and some of these factors are co-mediating such as precipitation through runoff and temperature through melting of snow (Ward et al. 2010; 2000b; Pasquini and Depetris 2007; Richey, Nobre, and Deser 1989; 2001; Potter et al. 2004; 2005). On a regional level, a study exploring the relationship between SST anomalies with temperature and precipitation from 1950 to 1995 in the Amazon found that on average El Niño years, expected rainfall was 83mm per year, which is a reduction of 4% when compared to the neutral conditions (Foley et al. 2002). During the La Niña years, there was an increase of 64mm per year of rainfall. When examining this trend at a higher resolution, the authors found that the northern region of the Amazon basin received a net decrease of 120mm per year in El Niño, and a net increase of 215 mm per year in the La Niña years. In parallel, a study of flooding (as a proxy for river discharge) found that the number of floods were suppressed in the El Niño cycles among river basins located in the central Amazon, and vice versa during the La Niña phases. Further, in the same study, authors constructed a predictive model where they utilized Southern Oscillation Index (SOI) to forecast flood levels, and found that 51% of the variance was explained by the index itself (Schöngart and Junk 2007).

In the last 10 years, Iquitos city in Peru has experienced three ENSO events. El Niño phases were identified in June 2004 to February 2005, August 2006 to February 2007, and June 2009 to March 2010. La Niña phases on June 2010 to March 2011 and August 2011 to April 2012. At that time, drought conditions in the 2005 El Niño phase has been one of the most extreme events observed, only to be surpassed by the drought conditions in 2010 (Marengo et al. 2008; 2011). In parallel, the flooding in 2009 was termed the "flood of the century", which was later surpassed by even higher record-breaking floods in 2012. Both of these occurred during the La Niña phase, particularly the 2012 flood where river discharge reached above emergency levels - 117m above the mean river discharge (Marengo et al. 2013a; Filizola et al. 2014). The 2012 flooding in the Amazon was particularly devastating as it increased the river discharge levels during the dry season. Shown in Figure 2-4 are the daily river discharge of Nanay from January to December by year from 2008 to 2013. The two big floods that occurred in 2009 (in blue dash) and in late 2011-2012 (black and red dash) are relatively higher in magnitude compared to other years.

Flooding patterns have important implications for livelihood patterns in the Amazon. Generally, in the dry season under optimal rainfall conditions, the vegetation re-grows when flooding from the river is at its all-time low. Dry season reforestation (June-November) is not only a critical element to the energy balance of the Amazon but it is also a period where there is increased availability of food for humans, in terms of both forest products and fisheries (Schöngart and Junk 2007). The wet season (December-May) is the primary driver of transfer of nutrients between terrestrial and aquatic ecosystems. It has been noted that flooding cycles have become more infrequent yet more intense compared to the productive flash floods. Generally, rivers in the tropical regions of South America (Amazon Basin) have low stream flow during the El Niño phase, and the rivers in the mid latitudes of South America are wetter during El Niño years. The reverse pattern occurs during the La Niña cycles.

Even though El Niño and La Niña are coupled cycles that occur naturally, there is concern that the number of extreme events is increasing with increasing climate variability and shift towards higher global mean temperature (Cai et al. 2014). Further exacerbating the situation are the drought conditions that occur during the wet season, and flooding conditions that occur during the dry season, which are also strongly associated with the ENSO cycles. In addition to the rise in extreme events, variations in rainfall during the El Niño vs La Niña cycles have large impacts on crop productivity and consequently may affect the food economy and dietary intake of those living in the Amazonian regions.

Research Questions

The integral aim of this project is to explore the impact of climate variation on child dietary intake, mediated though factors such as food prices. I have used the Food and Nutrition Security Conceptual Framework shown in Figure 2-5 to structure the design of the study (Ruel 2013). Shown in Figure 2-6 is the adapted conceptual diagram for the study aims with bold boxes indicating the key measures of interest.

Aim 1: Explore the relationship of climate variability on river discharge levels and on food prices in Peru, 2008-2015.

Objective 1: Evaluate the relationship between ENSO indices on river discharge level of Rio Nany, located in Loreto Province.

Objective 2: Evaluate the temporal associations between ENSO indices on weekly food prices [rice, eggs, yucca, plantains, sugar] from the Loreto province in Peru after adjusting for consumer price index inflation.

Aim 2: Evaluate the association between ENSO on frequency of meal consumptions patterns, amount of food consumed and dietary diversity among children 9-36 months of age (October 2010- October 2014) living in Iquitos, Peru.

Hypothesis 1: After controlling for covariates, meal frequency of the most commonly consumed foods should be lower during wet season and during El Niño and severe ENSO conditions. After controlling for socio economic factors, age, gender, morbidity, and energy intake, there should be higher intake (grams) of fish, rice, and sugar and lower intake of yucca and plantains during the dry season (June to November) and vice versa during the periods of El Niño and severe ENSO conditions. There should also be higher consumption of gifted foods (gifting foods is a common coping strategy in this community) during the wet season and El Niño and severe ENSO conditions.

Aim 3: Determine the extent to which ENSO conditions are associated with nutrient intake and micronutrient inadequacy ratio (NAR) in children 9-36 months of age in the MAL-ED cohort.

Hypothesis 2: After controlling for socio economic factors, age, gender, morbidity, and season, the periods of El Niño and severe ENSO conditions will be associated with lower macronutrient (energy, protein, carbohydrates) and micronutrient adequacy ratios for iron, zinc, calcium, vitamin A, vitamin C, vitamin B12, and folate.

Study Setting

The city of Iquitos, founded in 1757 is currently home to half a million inhabitants with a population density of 4.6 people/km^2. Figure 2-7 shows the city of Iquitos, located in northeastern Peru, in Loreto province (Mäki et al. 2001; Yori et al. 2014). Because of its remote location, it can only be reached by air and water. It is the largest Peruvian city with direct access to the Amazon River and is located approximately 3.7 ° S below the equator and 73.2 ° W. The region is classified as a tropical rainforest with an “Af” Koppen classification (Yori et al. 2014). Annual precipitation is 3400mm, and there is rainfall during 60% of the year. Primary drivers of the economy include the travel industry, fisheries and other natural resource products (timber, cocoa, nuts, forest products) and more recently mining, oil and natural gas industries (Swierk and Madigosky 2014; van

Soesbergen and Mulligan 2014). The current deforestation rate is 540 km^2 per year and the main causes of deforestation in the region are agriculture, and more recently, gold mining (van Soesbergen and Mulligan 2014). Deforestation has important implications for river flow and raises discharge variability via three ways – reduction in rainwater retention, rise in runoff, and low water quality. With given trends in climate and anthropogenic activities, projections estimate a 12% increase in rainfall (61mm) over time and consequently a greater imbalance in seasonal river flow (Sena et al. 2012; van Soesbergen and Mulligan 2014). As previously noted, flooding spikes have implications for human settlements in the Amazon because flood pulse behavior determines the biogeography of aquatic, terrestrial and human settlements (Schöngart and Junk 2007). Thus, ENSO events have cascade effects on the interconnected ecosystem, particularly on economy and trade as it relates fish availability, agriculture productivity, and forest products.

Seasonal river discharge plays a role in determining crop yields, household income and dietary intake. Figure 2-8 illustrates various crop yields by month in the Loreto region. Rice, yellow maize, melons, and pineapple are largely harvested in the dry season from September to November. Other staples such as plantains and yucca are available throughout the year, but may be consumed more in the wet season due to lower availability of rice and dry beans. Other crops such as coffee and cacao (not shown on the Figure 2-8) are also harvested in the dry season and are an important source of income in the region.

The proposed study is set in Santa Clara town, which is located 15 km away from the center of Iquitos City. Santa Clara is one of the primary producers of vegetables and fruits for the city, including lemon, papaya, onions, tomatoes, and cilantro. Not surprisingly, the primary occupation in the community is selling vegetables/fruits (15%), followed by fishing (8%), driving moto-taxi (8%), brick laying (6%), and working as a part-time wage laborer for the local lumber and gas industry. Occupations linked to procuring natural resources (fish, forest products) and agricultural products are also seasonal as evidenced by the crop calendar (Yori et al. 2014).

Previous studies examining seasonality in the context of agriculture in other regions of the world have found remarkable differences in dietary intake, especially energy, fat, protein, vitamin C and vitamin A intake among pre-school children (Brown et al. 1982a; 1982b; 1985; Hassan et al. 1985; Behrman 1988; 2015). Dietary intake has never been quantified previously in the Loreto region but a dietary study conducted in the neighboring Amazonia province of Ucayali from 1998-2001 showed 9 types of food typically consumed by children (n~1200) living in riverine settings. Documented are: fish (37 species), animal (chicken, eggs, pork, beef), game (deer, monkey, turtle, toucans, cranes), cereals/vegetables/legumes, cultivated fruit (avocado, apple, dale dale, grapes, lemon, orange, maracuya, plantain, watermelon, mango, papaya), wild fruit (aguaje, palm hearts, guanabana, caimito), oil/nuts/seeds (palm oil, palm seeds, peanuts), and processed foods (canned milk, powdered milk, canned tuna/sardines, bread, pasta). In this study, there were remarkable seasonal differences in food patterns, for example fish and processed food contributed the highest percent of energy during the dry season whereas cereals and animal meat consumption was highest during the wet season. Consequently, 36% of children 1-5 years of age were below adequacy for energy during the wet seasons with the mean intake of 395 kcal/d compared to 15% below adequacy during the dry season with the mean intake of 521 kcal/d. Similar patterns were observed in fat intake with 29, 16, 11 grams in dry, wet, and at the start of the rainy season, respectively; and also with carbohydrate intake with 238, 217, 195 grams in dry, wet & start of the rain season but not for protein because other sources of animal protein were substituted (such as game, poultry, eggs) during the wet season when there is low fish availability. Dietary diversity and quality were greater during the dry season as one would expect given the availability of fish and crop yields (see Figure 2-8). Although plantain was available throughout the year, the consumption increased by 50% during the start of the rainy season (December-January). In addition, the study also showed that there were inter-annual differences in the fat make-up of the fish, and the type of fish caught at different seasons was the likely cause of variability in fat intake among children. This study also found seasonal variation in energy, carbohydrate, protein, fat, vitamin A, zinc and iron intakes– all were higher in the dry season (Murray and Packham 2002).

Dietary adequacy is a critical element of nutritional security especially among children 0-5 years of age because it affects long-term growth and development. There are no studies in the Amazonian region examining the impact of ENSO, price hikes, and river levels on food intake, or intakes of minerals and vitamins. In this Peruvian Amazon, river discharges are the largest driver of seasons and the timing of these factors may play an important role in nutritional security. Factors that increase sensitivity and exacerbate the effects of climate variability include a population that relies heavily on natural resources for livelihood and dietary intake, high-income inequality, and lack of protection against economic volatility. Many of these aggravating elements are present in Iquitos, in addition to infectious disease burden.

Data sources

Shown in Table 2-1 are the data availability and sources of the key variables of interest in the current study. For Aim 1, climate variation factors like ENSO index, river level, temperature and rainfall were obtained from a longer period of time (1960-2013) to explore its long-term trend on food prices. Food prices were obtained from the Ministry of Agriculture (MINAGRI) and the National Institute for Statistics and Informatics (INEI) in Peru, where biweekly price data were available (See Figure 2-8 for study timeline for Aim 1). Information on ENSO indices were obtained from National Oceanic and Atmospheric organization (NOAA). Multivariate ENSO index (MEI) used primarily in this study, is comprised of sea level pressure differences, satellite measured ozone, and combination of multiple indicators using SST at different locations, sea level pressure, surface wind & air temperature and cloud density (Trenberth 1997; Kovats 2000; Haines et al. 2006; 2010; Ren and Jin 2011). The MEI index gives a twelve two month running average of SST each year (MEI time series, 2016). Positive number indicates warming and higher sea surface temperature and potentially an impending El Niño phase and vice versa for the cooler La Niña phase (MEI time series, 2016). These are readily available and free to download from the NOAA website (MEI time series, 2016).

For aims two and three, data collection was nested within an ongoing birth cohort called The Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development (MAL-ED) study. Prior to the start of the MAL-ED study in the community, there were meetings held with the community leaders describing the purpose of the study and the eligibility criteria to be enrolled in the study. List of pregnant mothers were compiled from the local health center, and was assigned to each field worker based on geographic location. After parturition, mothers and the head of the household were approached for consent to enroll in the study after initial screening of the newborns. The eligibility criteria for the MA-ED study are as follows 1) Mothers should be at least 16 years of age and have no plans to move out of the study area for the next six months; 2) newborns should have a birth weight of 1500 grams and be less 17 days old; 3) newborns should not have any congenital defects or any severe or major illness. Families were informed of voluntary participation in the study, and are have the option of withdrawing from the study at any time. Field staff and the PI, Dr. Margaret Kosek were available, should the family members have any questions or concerns about the study protocols. The Institutional Review Boards from the Ministry of Health in Peru and Johns Hopkins School of Public Health approved the informed consent. Information on mother-child recruitment and study setting are described in detail elsewhere (Yori et al. 2014). At baseline, demographic, food security, questions on early initiation of breastfeeding and morbidity were recorded. These assessments were conducted in home.

The MAL-ED Peruvian cohort enrolled 303 child-mother dyads, and extensive information on nutrition, morbidity, and vaccine response were recorded meticulously at a high resolution. Dietary data was collected when the children turned nine months of age, and because of the staggered enrollment, there are children turning nine months of age from October 2011 to November 2012. Data on dietary intake began at nine months because it was assumed that breast milk would be a huge component of the child’s diet in the first 6 months in accordance with the WHO policy where the first six months of exclusive breastfeeding is encouraged, and from 6-9 months, breast milk would still be a large component of the diet as the child transitions from liquid to mostly semi solid food

(Caulfield et al. 2014). By nine months of age, over 90% of the children in the cohort are partially breast fed (Lee et al. 2014). The timeline at the end of this section (Figure 2-9) shows the dietary intake collected for study aims two and three with respect to ENSO events. Since the start of the collection of dietary data, there have been two La Niña events and one El Niño event. The two La Niña events occurred from October 2010 to July 2011 and from December 2011 to March 2012).

Breastfeeding information was collected during the twice weekly nutritional surveillance with the mother queried about the child's intake and frequency of consumption in the previous 24 hours. These included breast milk, animal milks, formula, juice, tea, and specific solids (such as yogurt and grains). Breastfeeding definitions from Labbok & Krasovek were used to characterize each day as exclusive, predominant, partial or no breast milk in the diet (Labbok and Krasovec 1990).

Morbidity of the child was collected during the twice-weekly surveillance conducted by the field workers. Field workers queried the mother on illness symptoms for diarrhea, fever, loss of appetite, symptoms of dehydration, troubled breathing and ear pain. In particular, there was a focus on diarrhea and fever where the caregivers were queried on the number of loose stools, vomiting, visits to health center and the type of medication consumed. If there was diarrhea on the day of fieldworker's visit to the house, a sample was collected for laboratory assessment of bacterial, viral and protozoa pathogens. If there was fever on the day of the visit, the temperature of the child was collected. Illness prevalence were created based on the presence of diarrhea, fever, cough or vomiting and these were summed on a monthly basis (Richard et al. 2014).

The Water & Sanitation, Assets, Maternal Education and Income (WAMI) index created by Psaki et al utilized the “actual resources” approach to estimate the socioeconomic status among households enrolled in the MAL-ED study (Psaki et al. 2014). It included twelve indicators: access to improved water source and improved sanitation, 8 household assets (bank account, television, refrigerator, mattress, separate room for kitchen, table, chair, >2 people per room, maternal education in years, and monthly household income in USD. A household with a higher score is considered to be of higher socio economic status. These were used in the analysis as a measure of SES but these components were also assessed separately to examine if a particular aspect of the index exerts greater influence on food consumption and micronutrient intake patterns.

Weight measurements were collected monthly using Seca baby scale and they were recorded to the nearest 0.01 kg. On a monthly basis, the supervisor re-measured 5% of the weight measurements for quality control purposes. These quality control measurements were unannounced and were done within two days of the original measurements.

Because of the open enrollment in the cohort, there were groups of children with varied exposures to the weather shocks and price shocks. For example, there is a group of 9-15 month old children who experienced weak El Niño and subsequent shocks as they grew older; another subset of children 9-15 months of age experienced La Niña from December 2011-March 2012; and another subset children 9-15 months of age children that were not exposed to either of these shocks. Second and third aims would compare these various groups of children that are enrolled at different time periods. Since the comparison groups are at different time points, secular trends could be potential source of confounding. However, in this community, there have not been any introduction or changes in social programs since the start of the cohort that might contribute to the secular trends, accordingly, there would not be any confounding or secular trends.

Tables & Figures

Figure 2-1: Variable effects of ENSO around the world (Kovats et al, 2003)

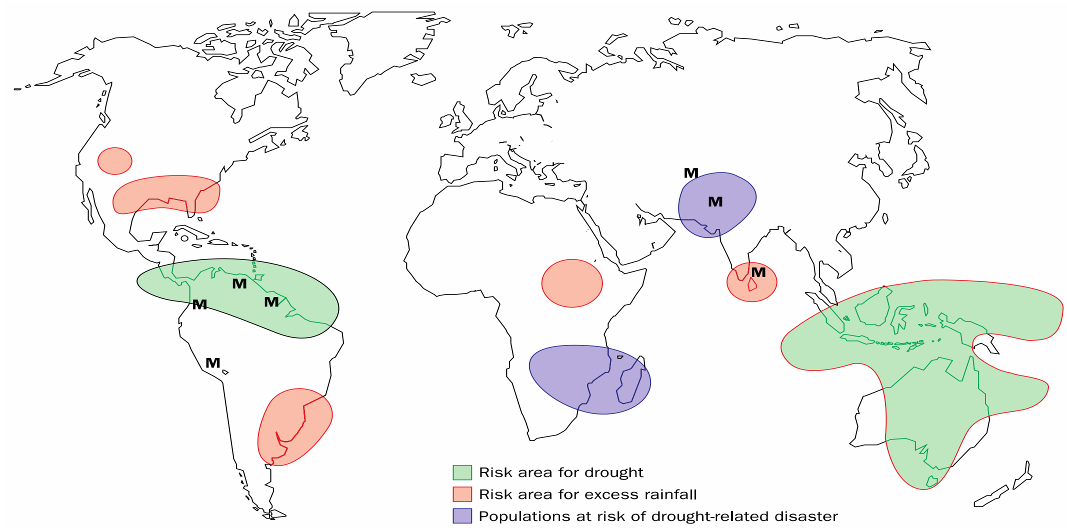
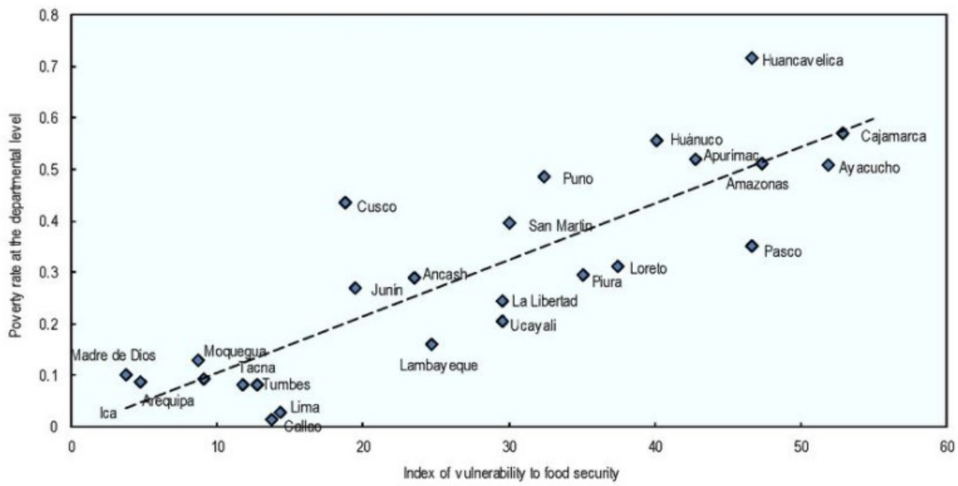


Figure 1: **ENSO teleconnections and risk map for malaria**
Risk areas for drought and rainfall based on teleconnections associated with El Niño.[4] M shows areas where there is a risk of epidemic malaria after the onset of an El Niño event.

Figure 2-2: Vulnerability to food insecurity by Peruvian provinces



Source: OECD analysis based on data from INEI.

Figure 2-3: Shifts in household expenditure before and after rise in the price of staples (Bouis 2011)

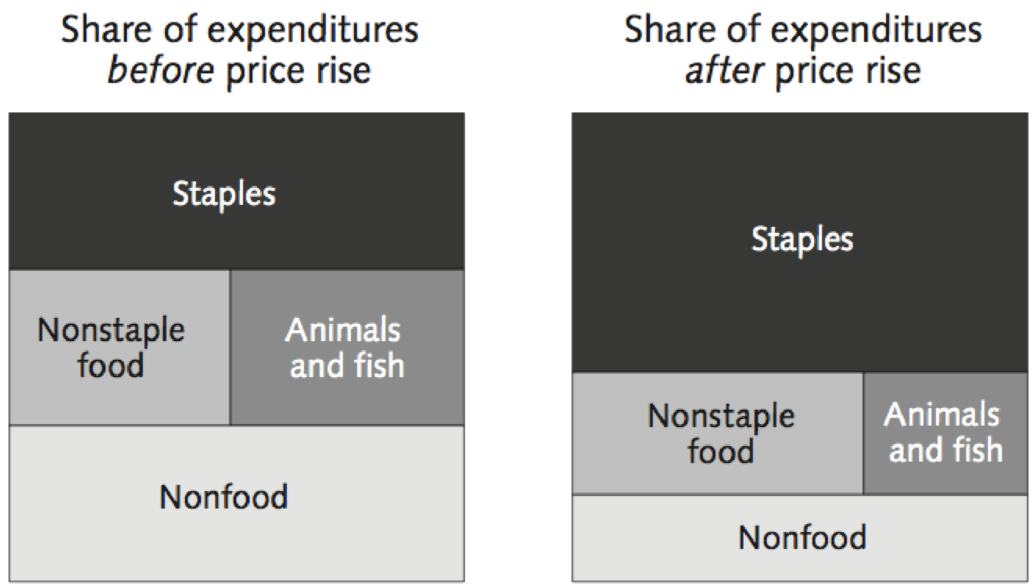


Figure 2-4: Annual seasonal river flow of Nanay (meters above sea level) by year 2008-2013

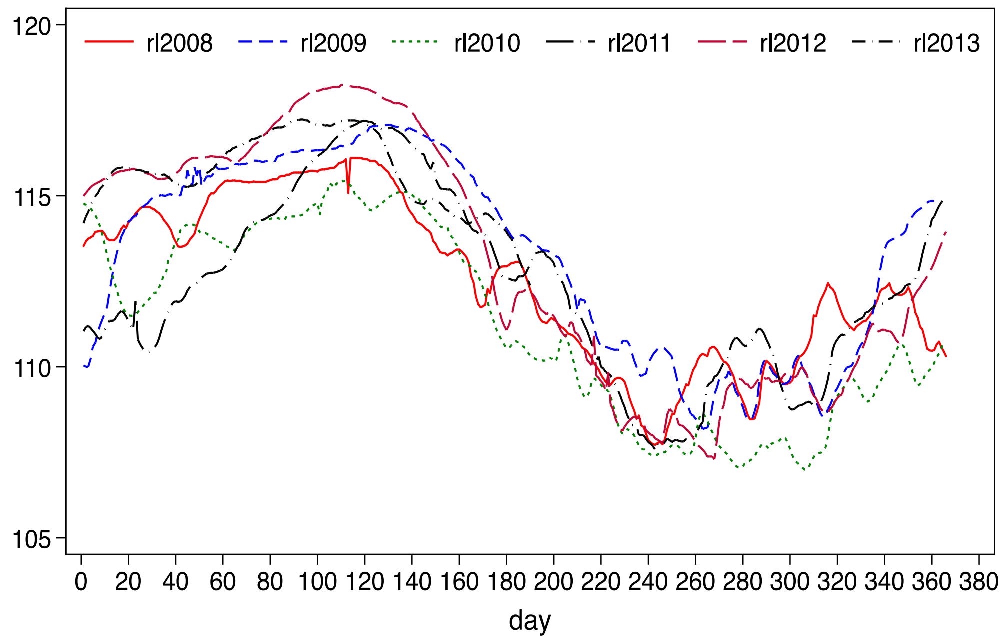


Figure 2-5: Food and Nutrition Security Conceptual Framework from the World Food Program (Ruel 2013)

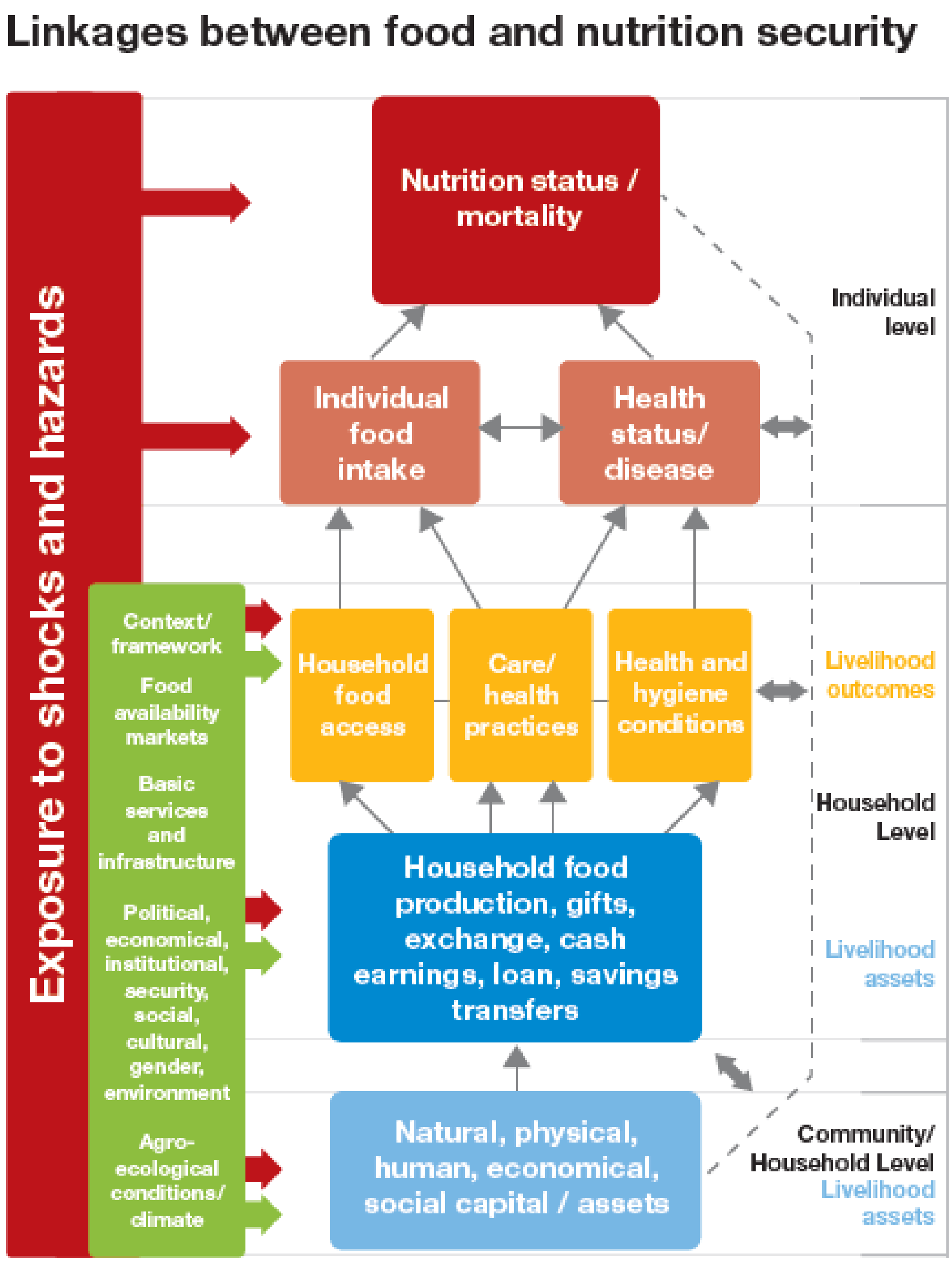
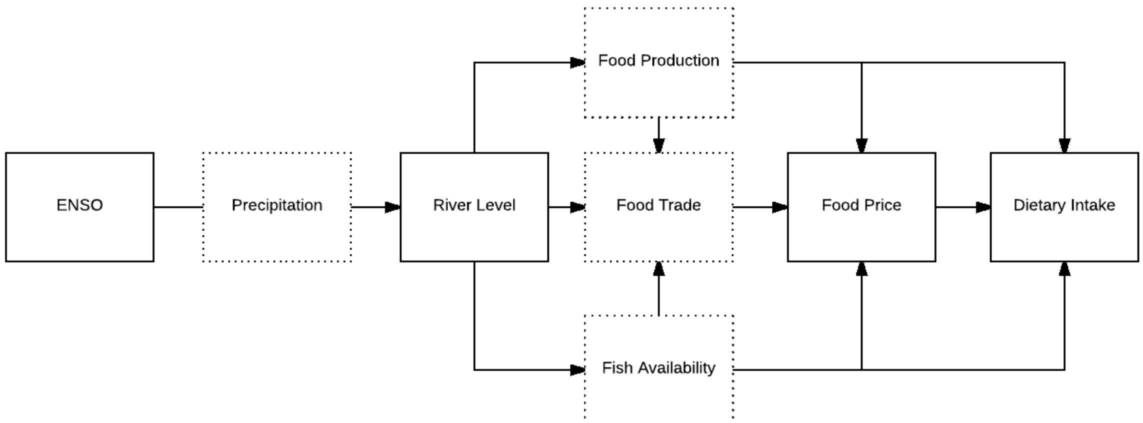


Figure 2-6: Conceptual diagram of impact of ENSO on dietary intake in the Peruvian Amazon.



Bold boxes indicate the key measures of interest and dotted boxes illustrate the mediating variables.

Figure 2-7: Map of Iquitos in Peru (Yori et al, 2014)

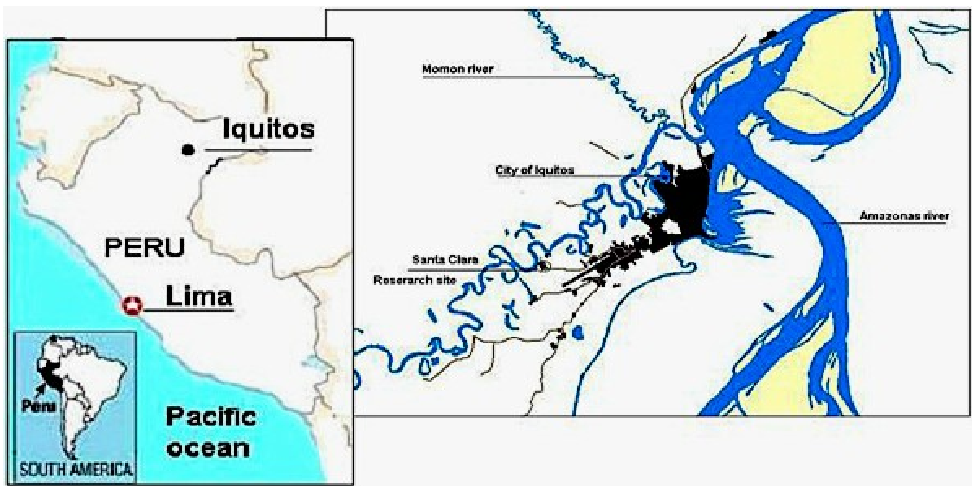


Figure 2-8: Crop Yields in the Loreto Region of Peru, by month

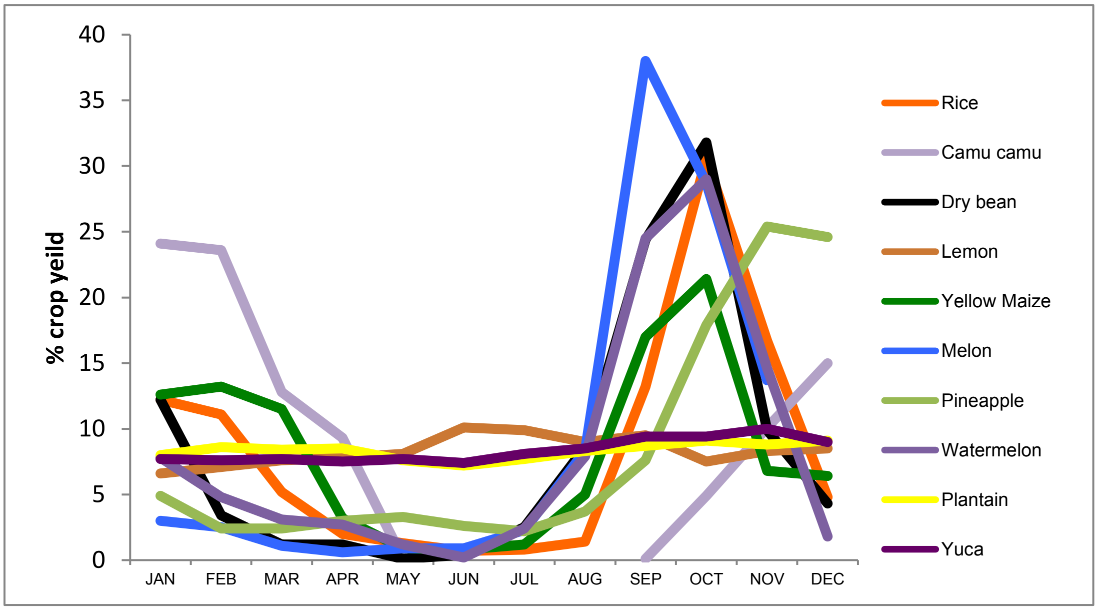
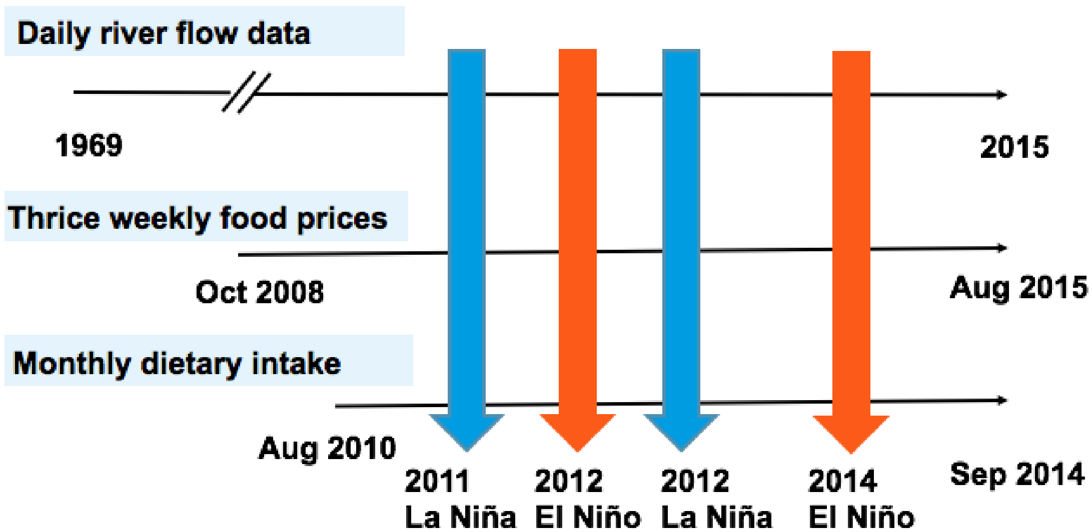


Table 2-1: Data availability for the current study

Data Category	Methods	Resolution and time	Key Variables / Sources
River level	(a) Meters above sea level of River Nanay	Daily	(a) Sedaloreto water treatment plant
ENSO index	(a) Multivariate ENSO Index (MEI) (b) Southern Oscillation index (SOI) (c) Oceanic Nino Index (ONI)	Monthly	(a) National Oceanic and Atmospheric organization
Food prices, Consumer price index	(a) Retail and Commodity food prices for markets in Loreto Province (b) CPI obtained nationally	Thrice-weekly	Peru Ministry of Agriculture (MINAGRI), Food and Agriculture Organization, and National Institute for Statistics and Informatics
Dietary intake	(a) 24- hour recall of infant feeding using maternal recall	Monthly	(a) Frequency of meals, Dietary Diversity, nutrient intake and adequacy ratio from the MAL-ED study
Breastfeeding status	(a) Status and frequency by maternal Recall	Twice weekly, from birth to 24 months	(a) Breastfeeding status based on WHO definitions from the MAL-ED study
Morbidity	(a) illness and diarrhea prevalence each month	Twice weekly, from birth to 24 months	(a) Combined illness score from the MAL-ED study
WAMI – SES index	(a) Water-Sanitation, Assets, Maternal education and income index (Psaki et al. 2014)	Semi-annual	(a) MAL-ED study
Weight	(a) Measured in Kg using Seca baby scale	Monthly	(a) MAL-ED study

Figure 2-9: Study timeline for the research aims.



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Chapter 3 : El Niño Southern Oscillation Affects Food Prices Through River Variability In The Peruvian Amazon

Abstract

Many studies have illustrated the associations between El Niño Southern Oscillation (ENSO) on world food prices. However, there are has been no studies linking the association with mediating ecological factors. In Peru, ENSO has had a long history of causing havoc in the economy and infrastructure. There have been no studies linking the association of ENSO on regional food prices in Peru through mediating factors such as river discharge levels. In the first set of analysis, three different ENSO indices (Oceanic Niño Index (ONI), Southern Oscillation Index (SOI), and Multivariate ENSO index (MEI)) were chosen to examine the relationship with the daily river level data from Rio Nanay from years 1969 to 2015. MEI index and severity variable showed the best fit for predicting river level. In the second analysis, all three indices along with severity variable and river discharge levels were used to examine temporal association with regional food prices. Locally produced foods such as yucca, eggs and sugar were more responsive to severity and river levels. In contrary, MEI on rice shows a decrease of food prices by 0.02 SD while river level increases rice prices by 0.02 SD, and neither of these impulse response functions stabilize in the long run, suggesting permanent long term impacts of ENSO shocks.

Introduction

El Niño Southern Oscillation (ENSO) is a naturally occurring oceanic-atmospheric interaction in the Pacific Ocean, which drastically affects temperature and precipitation patterns around the world. Although the phases of ENSO (El Niño and La Niña) occur over 2-7 year cycles, there is growing concern that the variability and severity of ENSO cycles are correlated with a rise in global temperature due to climate change (Cai et al. 2014).

Due to variable crop production during ENSO events, many studies have posited and attempted to quantify a causal link between ENSO, world economy and food price fluctuations (Brunner 2002; Hansen, Jones, & Kiker, 1999; Ubilava 2014; Ubilava & Holt 2013). In Peru, the effects of ENSO on food systems have been readily observed during each cycle since the 1950s. During the 1972 El Niño, there was catastrophic damage to the coastal fisheries, leading to a nationalization of the fishing industry. The record-breaking El Niño cycle in 1982-83 caused heavy damage to crop yield and infrastructure, during which some regions of Peru "received seven years of worth of rain in four months" (Caviedes 1985). Crop failures were rampant, with rice, potatoes, cotton, sugar cane, and alfalfa losses valued at USD 244 million (USD 596 million in 2013) (Caviedes 1985). This was termed an "environmental-ecological crisis" due to cyclical damages on infrastructure, health and the economy (Caviedes 1985). In the 1997-98 ENSO cycle, the coastal region of Peru reported 3300 millimeters (mm) of rain when the average rainfall is usually less than 200 mm (Bayer et al. 2014). Soil moisture content in this area was 2.5 times above normal, causing a large loss in rice and banana production, and consequently, food price hikes followed (Danysh et al. 2014). To date, there has not been a single systematic study examining the effects of ENSO on food prices in Peru, although there have been media reports of price hikes subsequent to every strong ENSO event (Bayer et al. 2014b; Caviedes 1985; Reuters).

In the Peruvian Amazon, ENSO plays a large role in river discharge (Lavado-Casimiro, Felipe, Silvestre, & Bourrel 2013). A study of flooding (as a proxy for river discharge) found that numbers of floods were suppressed in the El Niño cycles among river basins located in the central Amazon, and vice versa during the La Niña phases (Schöngart & Junk 2007). In the same study, the authors constructed a predictive model utilizing the Southern Oscillation Index (SOI) to forecast flood levels and found that 51% of the variance was explained by the index itself. Flooding patterns have important implications for livelihood patterns in the Amazon. Generally, in the dry season (June-November) and under optimal rainfall conditions, the vegetation re-grows when there are fewer floods. During the dry season when the river levels are lower, there is greater access to forest products (especially in the interior areas), and increased economic activities between the riparian communities. However, due to the rise in extreme weather events during the El Niño and La Niña cycles, there has been an increase in flood events, with impacts on river discharge and perhaps on the food economy and dietary intakes of those living in the Amazonian region.

Study Hypotheses

Despite many studies linking ENSO events to crop productivity and food prices, very little work has been published examining how these effects are mediated in Peru, particularly in the Amazonian region. The aim of this report is to (1) examine the relationship between ENSO and the hydrological variability of the Rio Nanay, located in the northeastern province of Loreto, Peru; (2) establish the effect of the relationship between ENSO and the Rio Nanay on food prices in Loreto province. This is the first of three reports examining linkages between climatic, seasonal, and environmental factors on food prices, dietary intake and nutrient adequacy among children in the Peruvian Amazon.

Methods

Iquitos, Amazon

The city of Iquitos, located in the Loreto province in northeastern Peru, is a riverine community in the midst of global environmental change. The Amazon, Itaya, Napa, and Nanay Rivers surround this island city which can only be reached by air or water (Yori et al. 2014). In Iquitos, subsistence fishing and local markets provide about 75% of fish production (Garcia 2008). Dietary intake primarily consists of seasonally available produce. River levels impact the production and transportation of food, and access to fish and forest products in the Peruvian Amazon, and hence represent a critical aspect of the economy in Iquitos. (Mäki, Kalliola, & Vuorinen 2001; Sherman 2014).

Study Design

The analysis is divided into two parts. First, the association between river discharge (Nanay River) and ENSO index is evaluated using daily river data from 1969 to 2015. Second, associations between river discharge and ENSO on food prices are evaluated using a dataset of thrice-weekly food prices from 2008 to 2015.

Measures

Part 1

Although the overarching goal is to examine the impact of ENSO cycles on food consumptions patterns, assessment of how ENSO affects river variability is key to understanding the pathway. Daily river discharge (meters above sea level) from February

1, 1969 to August 21, 2015 from the Rio Nanay was obtained from the Sedaloreto water treatment plant located in Iquitos Peru (n=16,856; data missing for August-September 1969). Variables for monthly mean, median, maximum and minimum were created. Three monthly ENSO indices were selected as key exposure measures: Oceanic Niño Index (ONI), Southern Oscillation Index (SOI), and Multivariate ENSO index (MEI). These indices measure different aspects of the ENSO strength and duration, and thus can vary in sensitivity in accurately capturing the ENSO phenomenon (Hanley, Bourassa, O'Brien, Smith, & Spade, 2003). The midpoint of the three month running average was treated as the monthly ENSO value for a given month; i.e. the average of the values for December, January, and February of 1969 were assigned to January 1969. An 'enso' variable was created to indicate neutral (-0.4 to 0.4), El Niño (≥ 0.5) or La Niña (≤ -0.5) conditions. Further, two continuous variables from the 'enso' were created for the two phases, because current evidence indicates to differential impacts by phase (Ubilava & Holt, 2013). From the indices, a 'severity' variable was created for both phases of ENSO: weak (0.5 to 0.9) moderate (1.0 to 1.4), strong (1.5 to 1.9) and very strong (≥ 2.0). All indices were created to align in the same direction.

Part 2

Thrice-weekly food price data for the Loreto province was obtained from the online database Information on Supply System and Prices (SISAP), an online database from the Peruvian Ministry of Agriculture and Irrigation (MINAGRI). Rice, white sugar, yucca, plantain (belaco variety), and egg prices were downloaded (on May 2nd, 2016). The last three foods are often interchangeably consumed as the main staple depending upon the food security of the household. For example, yucca is substituted for rice and plantain substituted for rice and yucca in food insecure households as rice is the more expensive. All units are in Peruvian Sol (S/.) per kilogram, except for plantains, which are per cluster (*racimo*). Monthly Consumer Price Index (CPI) for a food basket was obtained from the Central Reserve Bank of Peru to adjust for inflation (BCRP). Food prices were adjusted to the May 2016 CPI rate. Although data were available from January 2008 to May 2016, there were large data gaps from January to October 2008, during which there were only 11 observations present; accordingly, these were excluded from the analysis. The median temporal gap between food price data points was 2 days, with an inter-quartile range (IQR) of (1,3). Weekly means of food prices were estimated. Missing gaps were filled with the previous value in the series. River discharge data were only available up until August 2015, and accordingly, food prices after these dates were excluded from the analysis.

Statistical analysis

For the first analysis, scatter plots were generated and correlation analyses were conducted for river discharge variables and for each of the ENSO indices. Regression analyses were conducted to examine the association of ENSO phases and severity after adjusting for season (month). Further, interaction terms between severity and month variables were tested. Timing of minimum and maximum river discharge were examined, and tested for differences between years with neutral and El Niño conditions, and neutral and La Niña conditions using the Wilcoxon rank-sum (Mann-Whitney) test for non-normal distributions.

For the second analysis, each food price time series was explored for stationarity and tested for unit root using the Augmented Dickey-Fuller test (Diebold 1998). Following the methods of Brunner, multiple vector autoregressive models (VAR) were estimated for each food price series (Brunner 2002) with either 'enso' or 'severity' variables after adjusting for season (month), and river level. VAR models explain the impact of covariates on current food prices after adjusting for previous lags of the food prices, thus there is no omitted variable bias. Three different VAR models were estimated for each of the three ENSO indices. The first VAR model (A) included severity (9 values), the second VAR model (B) included ENSO as a categorical variable (neutral, El Niño, La niña), and the third VAR model (C) included two continuous values of indices for the two phases. Three different VAR models were estimated for each of the three ENSO indices. A merit of VAR models is that they are flexible enough to capture dynamics as complex as those exhibited by ENSO, river variability and food prices (Bjørnland 2016; Diebold 1998).

Temporal lags for the VAR models were chosen using the likelihood test, and guided by the Hannan and Quinn's Information (HQIC) and Schwarz's Bayesian Information criteria (SBIC). For each VAR model, coefficients were checked for stability, and residuals were checked for autocorrelation. The final model was selected based on SBIC. Granger-causality tests were performed for the VAR models to examine the temporal relationships. Impulse response function graphs were estimated for the interpretation of the coefficients from the VAR models. Adjusted Benjamini-Hochberg adjusted P values were used by multiplying the ratio of the rank and overall number of tests with the false discovery rate of five percent. This was conducted for the main VAR models under MEI index that were stable and did not have residual autocorrelation (McDonald, 2009). P value <0.05 were used as the cutoff to determine statistical significance. All analyses were performed in Stata version 13.1 (StataCorp 2013).

Results

Daily discharge of Rio Nanay ranges from 103.1 to 118.9 meters (above sea level) in a year, and has a unimodal peak in April. The dry season begins when river levels recede starting in June, reaching their lowest levels in September. Figure 3-1, panel A depicts the seasonal pattern from 1969 to 2015, where each line represents a year, while panel B focuses from 2008-2015 when food prices from the Loreto regions are available. The number of observations that fall under different ENSO phases and severity are show in the Table 3-1, where differences in ENSO characterization by each index are evident. Although on average, yearly maximums tend to occur earlier (~12 days) during an El Niño event and later during a La Niña (~18 days) event when compared to neutral conditions, these results were not statistically significant. Similar results were noted for yearly minimums, and again, the results were not significant.

When mean monthly river levels were examined by ENSO phases, there were differences observed by month, especially in the dry season; hence an interaction term with ENSO phase or severity with month was included in the regression models. Presents in Table 3-2 are the regression results from two models that were performed with each of the three indices, and for brevity, only ENSO and severity variable coefficients are presented. Overall, there was greater agreement between all three indices in the wet season (January to May), and greater discordance between the indices for the dry season, particularly from June to September. In the first model, there was great agreement that river levels were reduced by El Niño severity across all three indices, and particularly that the magnitude of this impact from the weak and strong El Niño were greater than that of moderate El Niño. With respect to La Niña severity, there is less agreement across the three indices. All models had R^2 above 0.69, and based on AIC, MEI with severity variable (model 2) has the best fit. These results guided the model building for food prices analysis.

Food price series for the five commonly consumed items are shown in Figure 3-2. Eggs were the most expensive food item, with an average of S/. 3.48 (Standard Deviation [SD]: 0.59), followed by sugar with S/. 1.99 (SD: 0.39), then rice S/. 1.92 (SD: 0.33), yucca S/. 1.18 (SD:0.46), and finally, plantains with S/.0.59 (0.09). All prices are per kilogram, except for plantains, which are priced per bunch. All price, ENSO variables, and river level series were stationary [i.e.I(0) processes]. HQIC criteria identified three lags for the VAR models with high concordance with SBIC criteria. Among the 15 VAR models, six had residual autocorrelation and were accordingly excluded (see table 3-4 on excluded models). Many of the non-stable VAR models were mostly sugar prices, and the reasons for these observed results are discussed later. The Granger causality of the remaining nine models are summarized in Table 3-1. The majority of the models with the smallest BIC are VAR models A with the ENSO severity variable. The temporal effects of river level are observed for yucca, eggs, and plantains but not for rice or sugar. Associations between month with yucca and eggs in two models indicate there is seasonality in these food prices that drives, particularly with eggs where the adjusted p values are less than 0.05. Both phases of MEI severe conditions have strong associations for yucca and rice. While egg prices are marginally associated with La Niña, and plantains prices are marginally with El Niño (adjusted p-value<.09).

Sensitivity Analyses with other ENSO indices

Although rice prices appear stable with MEI index, other indices show that models are not stable and/or there is residual autocorrelation. Interestingly, opposite is observed for sugar prices, where sugar prices have residual autocorrelation by MEI index, while under ONI and SOI model, they appear stable. For eggs, there is greater agreement among the indices that river level and month Granger cause the prices. With the SOI index, severity of ENSO does Granger cause eggs prices (model #31), and much of it is driven by La Niña (model #33). Interestingly, under the MEI index, only El Niño conditions Granger cause river level, while month and La Niña directly Granger cause egg prices. With regard to sugar, the majority of models indicate that ENSO severity and month Granger cause the prices. In one model (#12), this effect seems to be driven by La Niña conditions. Among all the food prices, plantain prices show the strongest effect of ENSO on food prices through river levels. The results of the models indicate that river level Granger causes plantain price, however model #45 shows that El Niño conditions may also affect river level (p-value = 0.089). Similarly, there are strong direct links between severity of ENSO, type of ENSO phase, river levels as they all Granger cause yucca prices. For rice, only two models under the MEI indices show that ENSO, in particular, La Niña conditions affect prices. It would be important to note that all the 45 models estimated indicate that ENSO is an exogenous event (i.e., lags of river level or month or prices do not influence ENSO phenomenon).

Impulse Response Functions

Impulse response functions (IRF) were used to examine exogenous shocks on the covariate of interest (severity, river level, months) and present a simple way of looking at their long-term impact and stability. In Figure 3-3, the impact of MEI surprises and river level on yucca, sugar, eggs, plantains prices are shown. Along the y axis is the standard deviation of prices and in x axis is time in days, the line in the middle is the effect with these two lines at the top and bottom represent 95% confidence interval. With yucca, severe

ENSO events cause a slight dip in prices that continues in the long term, whereas river level weather shocks cause an "up-down" effect in prices but the 95% confidence interval crosses zero (Brunner 2002). With sugar, severe ENSO cause hike in food prices by about 0.01 SD and river level doesn't seem to affect it. With regard to eggs, there were no differences observed for severe El Niño event but La Niña event causes a slight dip in prices. Finally, there were not effect of either MEI or river level on plantain prices. Shown in Figure 3-4 are the yucca prices by three ENSO index (model A). Here, there is a greater agreement between the MEI and ONI indices in the longer term, where yucca prices decrease after the second lag and prices remain lower for an extended period of time. In the short term, both ONI and SOI indicate a price hike in yucca within two days. All three indices suggest that changes in river level results in spikes of yucca price by 0.02-0.04 standard deviations (SD), before stabilizing around the fourth day. The MEI impacts on yucca prices shown in the IRFs indicate that prices do not stabilize back to zero, thus creating a permanent effect on yucca prices in the longer term. With eggs, there is a small decrease in prices by 0.02 SD on the second day after an ENSO surprise (ONI index), and similar decrease is observed for the river level. Sugar prices show similar effects as yucca where there is an initial "up-down" effect, which results from the SOI ENSO event (Brunner 2002). In contrary to all the locally produced foods, MEI ENSO events on rice shows a decrease of food prices by 0.02 SD even river level increases rice prices by 0.02 SD, and neither of these IRFs stabilize in the long run (results not shown).

Discussion

This report aimed to characterize the relationship of ENSO events and river level in the Peruvian Amazon, and consequently how these effects translate to shifts in food prices in the region. Since 2008, Peru has observed both weak and moderate El Niño and La Niña (with all three ENSO indices). While SOI categorizes several of the phases as stronger La Niña (i.e., moderate to strong la Niña), MEI tends to categorize some of these as stronger El Niño (i.e., moderate to stronger El Niño). In the first analysis, all three ENSO indices indicate reduction of river discharge, even after adjusting for seasonal flows. SOI and MEI indicate positive river discharge with varying severity of the La Niña event. These findings corroborate previously published reports on river hydrology in Peru by Servicio Nacional de Meteorologıa Hidrologıa (Lavado-Casimiro et al. 2013), and are consistent with overall general river flows in the western Amazon basin (Liebmann & Marengo 2001; Poveda et al. 2001). When these effects were examined by month, higher levels of discharge were observed during the dry seasons during an El Niño and vice versa, using the MEI index. When monthly discharge was examined by severity (model 2, Table 3-1), only the moderate El Niño indicated the general pattern, whereas weaker El Niño showed lower discharge during the dry season and higher discharge during the wet seasons. Hence, both severity and ENSO phases matter, and there may be potential synergistic effects of these factors on the local food economy.

In the second part of the analysis, we have identified a relationship between ENSO severity and river levels on the regional food prices using VAR models. VAR models examined food prices as a linear function of lags of the price series, and lags of all the other independent variables. Across the three indices, models with the ENSO severity variables showed the smallest BIC. Using Granger causality tests, we showed that seasons affect the prices of eggs, yucca and sugar, while river level influenced the prices of eggs, yucca, and plantains. It is possible that some of the river level impacts are captured by the season variable, and thus the true effect may be underestimated. Rice prices remain the most resistant to changes in the ENSO or river level, suggesting that government policies such as the reduction of taxes and tariffs on food imports are offsetting the negative impact and stabilizing potential weather-related price volatility (FAO). An ENSO shock reduced egg and rice prices by 0.02 SD while prices increased for plantains, yucca, and sugar.

There are multiple pathways through which prices are affected by ENSO, from both supply and demand perspectives (Ubilava 2014). Crop failures would be considered "direct supply" impacts whereas impediments to transportation during the delivery of cereals to the market would be considered "indirect supply" effects as in this case, where there is a ban on river travel when discharge reaches the emergency level of 117 meters above sea level (Ubilava 2014). Recent study from Nepal beautifully illustrated the large role of transportation (road network and bridge infrastructure) on rice and wheat price volatility, after accounting for crop productivity, transmission, and fuel cost (Shively & Thapa, 2016). The authors showed that in remote, isolated, and mountainous regions where road construction is expensive and sparse, food prices were associated strongly with road density (Shively & Thapa 2016). From the demand perspective, countries that were previously self-reliant for crops may import cereals during ENSO years, when there is persistent crop loss (Ubilava 2014). Many of these effects are evident after an ENSO event, particularly in Latin American countries that are directly affected by both phases of ENSO.

Recent studies have emphasized the importance of characterizing the non-linearity of ENSO events with food prices and in addition, focusing on the differential effects by phases of ENSO to model the phenomenon more appropriately. Ubilava et al showed that the El Niño phase was associated with 3% decrease in wheat prices, whereas La Niña was associated with 5-7% price increase in Canada, US, Europe and Argentina (Ubilava 2014). Further, the author suggests that autocorrelations between the two phases of ENSO have stark differences, in parallel with the climatology research warranting more attention and care to model the El Niño and the La Niña components separately. In parallel, food price hikes also show non-linear movement due to the dynamics of supply-demand, storage behavior, and market transmission (Pede, Valera, & Alam, 2013). Based on our analyses, we want to highlight that the severity of ENSO phases could potentially have differential impact, in addition to non-linear impacts of El Niño vs La niña, which needs to be explored more carefully in any future work related to world food prices.

There are several strengths to this study: First, we characterized the impact on ENSO on river hydrology and then examine how these effects translate to food price fluctuations. Second, we examined three types of models by three types of ENSO indices, and compared several different models of food series to quantify the effects. Limitations of this study include the following: (1) lack of analysis of co-integration of food prices with each other, (2) price transmission with the neighboring provinces and national food prices. Most of the consumed rice is produced within Peru, it's possible that any ENSO effect seen at the national level would also translate to regional level (FAO). In addition, there are reports of illegal food trade of sugar (and chicken and wheat) in Peru that could confound some of the observed relationship (FAO). These are hard to capture and characterize in these analyses.

Recently, one other descriptive report that examined river hydrology with the regional food prices in the western Amazon (Ronchail et al. 2015). The authors showed that prices of locally available foods are higher during floods, and there was a greater meat availability when the supply of fish is lower (Ronchail et al. 2015). However, this report did not show the impact of ENSO on river hydrology, and further they did not quantify the association between river discharge variability to local food prices. An estimated 1.6 million people live in the Peruvian Amazon, where the food economy is intrinsically tied to the riverine ecosystem. Climate impact to the ecosystem likely affects the food security in these communities.

Tables & Figures

Table 3-1: River level observations categorized by ENSO severity from 1969-2015 and food price observation from Oct 2008- Aug 2015, shown in parentheses.

Severity	ONI	SOI	MEI
Neutral condition	8,116 (1308)	7,479 (969)	6,538 (940)
Weak El Niño	2,462 (336)	2,366 (301)	3,402 (518)
Moderate El Niño	1,082 (198)	1,270 (111)	1,246 (211)
Strong El Niño	422	245	823 (90)
Very strong El Niño	214	209	780 (51)
Weak La Niña	2,796 (453)	2,401 (489)	1,817 (393)
Moderate la niña	1,456 (212)	1,764 (273)	1,460 (61)
Strong la niña	308	788 (213)	790 (243)
Very strong la niña		334 (151)	

Figure 3-1: Daily River level of Rio Nanay. Panel A shows the entire dataset, while Panel B shows data from 2008 onwards when food price data is available.

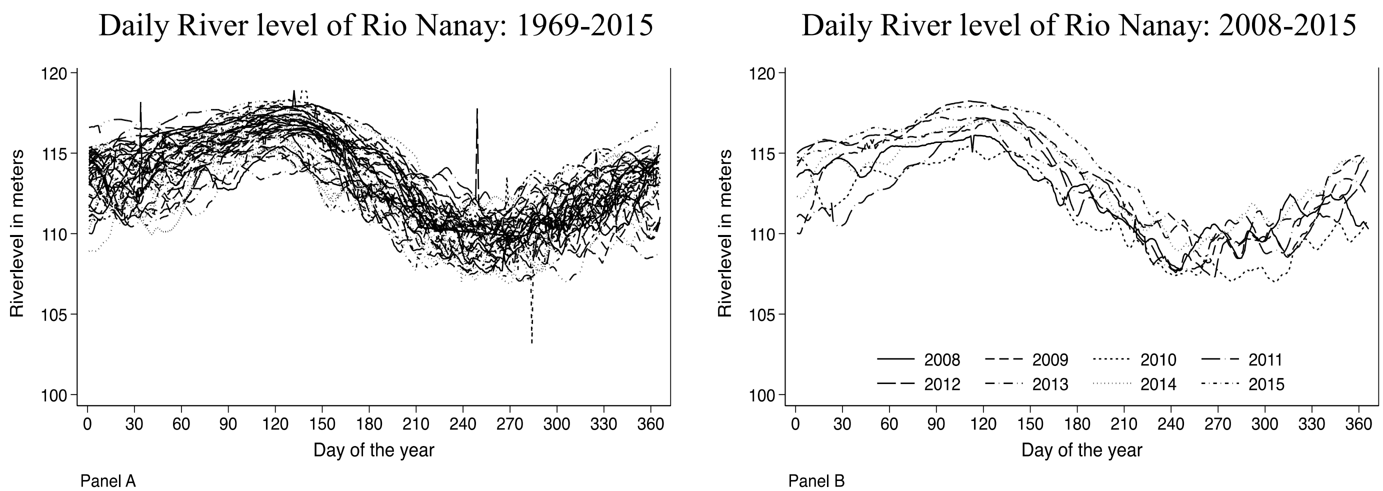


Table 3-2: Results from the regression model of river level of Rio Nanay from 1969-2015

	Model 1: River level = month + enso + sev + month*enso			Model 2: River level = month + sev + month*sev		
	ONI	SOI	MEI	ONI	SOI	MEI
Neutral condition	Reference					
El Niño	0.982^{***} [0.726,1.239]	1.850^{***} [1.594,2.106]	0.389^{***} [0.190,0.587]			
La niña	0.298^{*} [0.0651,0.531]	-0.362^{***} [-0.575,-0.150]	-0.0100 [-0.206,0.186]			
Neutral condition	Reference					
Weak El Niño	-0.815^{***} [-1.017,-0.614]	-1.429^{***} [-1.630,-1.227]	-0.467^{***} [-0.575,-0.358]	-0.110 [-0.314,0.0953]	0.00342 [-0.236,0.242]	-0.941^{***} [-1.178,-0.705]
Moderate El Niño	-0.597^{***} [-0.809,-0.385]	-1.658^{***} [-1.865,-1.450]	-0.364^{***} [-0.491,-0.237]	0.707^{***} [0.342,1.071]	0.127 [-0.111,0.365]	0.231^{*} [0.00913,0.453]
Strong El Niño	-0.462^{***} [-0.701,-0.223]	-2.090^{***} [-2.349,-1.831]	0.0650 [-0.0729,0.203]	0.0711 [-0.293,0.436]	0.175 [-0.175,0.524]	-0.0133 [-0.359,0.333]
Very Strong El Niño	0 [0,0]	0 [0,0]	0 [0,0]	2.485^{***} [2.120,2.849]	3.406^{***} [2.925,3.886]	2.400^{***} [2.054,2.746]
Weak la niña	-0.187^{*} [-0.363,-0.0119]	0.482^{***} [0.313,0.651]	-0.0404 [-0.159,0.0779]	0.230^{*} [0.0255,0.435]	0.787^{***} [0.527,1.046]	0.459^{***} [0.259,0.659]
Moderate la niña	-0.607^{***} [-0.790,-0.424]	0.469^{***} [0.305,0.634]	0.263^{***} [0.141,0.386]	-0.398^{**} [-0.652,-0.144]	-0.171 [-0.381,0.0388]	-0.383^{**} [-0.641,-0.125]
Strong la niña	0 [0,0]	0.598^{***} [0.416,0.780]	0 [0,0]	0.0491 [-0.259,0.357]	-0.389^{*} [-0.741,-0.0374]	-0.514^{***} [-0.804,-0.224]
Very Strong la niña		a			-0.194 [-0.487,0.0986]	

Observations	16856	16856	16856	16856	16856	16856
R^2	0.699	0.707	0.703	0.716	0.728	0.735
AIC	59061.2	58625.9	58833.3	58145.1	57460.7	57033.7

95% confidence intervals in brackets; [*] $p < 0.05$, [**] $p < 0.01$, [***] $p < 0.001$; [a] Very Strong La Niña was classified by SOI but it was captured in the month-enso interaction that are not presented here.

Figure 3-2: Food Prices from Loreto, Peru. Reference line at Aug 2015 indicates the cutoff for statistical analysis due to the availability of river discharge data.

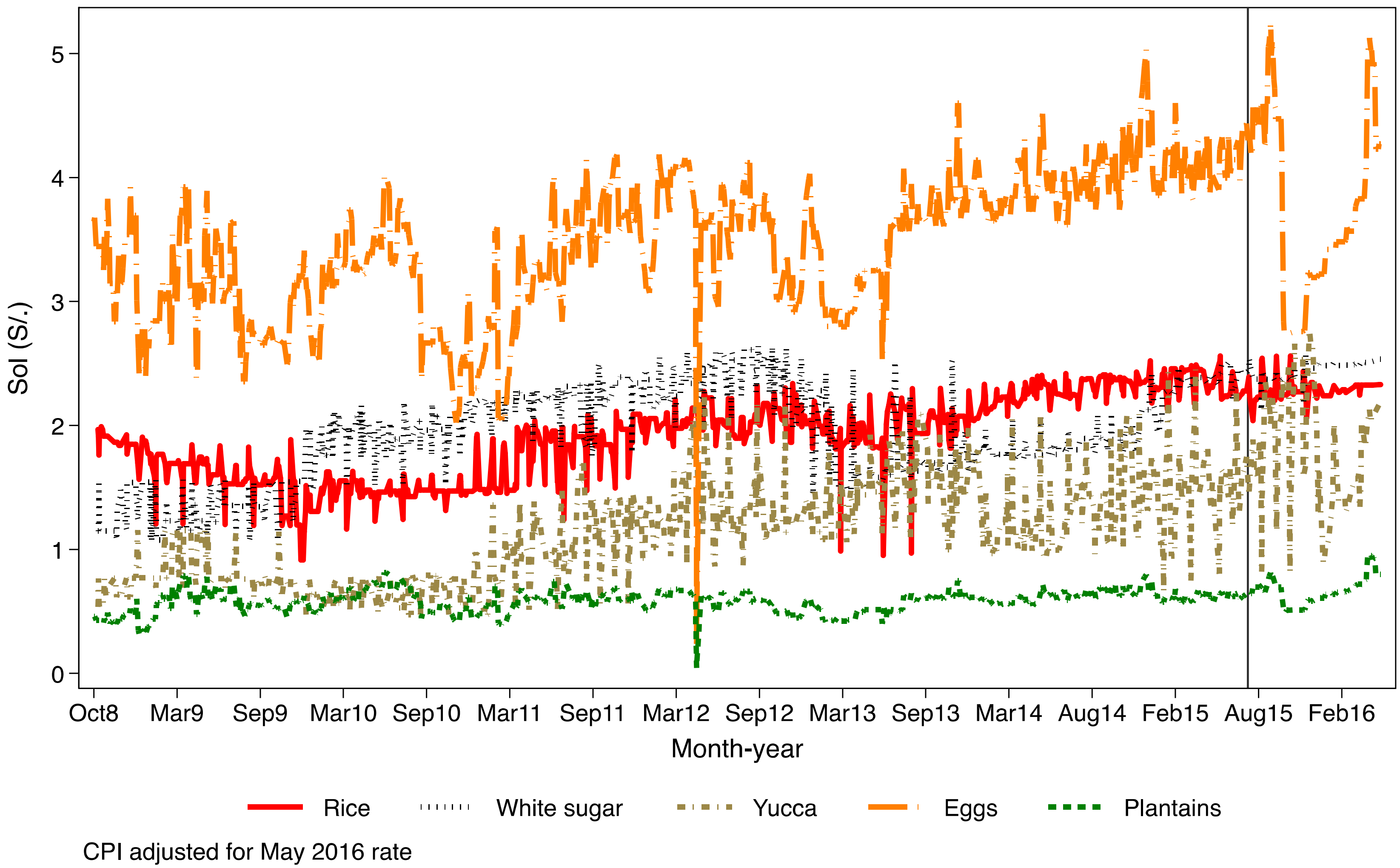


Table 3-3: Granger Causality of the VAR models with MEI index. Does variable A Granger cause variable B?

VAR Model	**ENSO index**	**A**	**B**	**pvalue**	**BIC**	**Stable?**	**Residual autocorrelation?**	**Rank**	**Benjamini-Hochberg adjusted p-value**
a	MEI	mei_sev	rice	0.004	-3211.827	Yes	no	5	0.014
b	MEI	mei_enso	rice	0.004	-4919.064	Yes	no	6	0.012
c	MEI	mei_lan	rice	0.07	-8792.577	Yes	no	14	0.090
a	MEI	mei_sev	yucca	0.002	-2392.913	Yes	no	3	0.012
a	MEI	River level	yucca	0.071	-2392.913	Yes	no	15	0.085
b	MEI	mei_enso	yucca	0.004	-4097.792	Yes	no	7	0.010
b	MEI	River level	yucca	0.035	-4098.792	Yes	no	9	0.070
b	MEI	month	yucca	0.056	-4096.792	Yes	no	12	0.084
c	MEI	mei_lan	yucca	0.002	-7993.172	Yes	no	4	0.009
c	MEI	mei_eln	yucca	0.061	-7993.172	Yes	no	13	0.084
b	MEI	month	eggs	0.001	-5517.379	Yes	no	1	0.018
b	MEI	mei_enso	River level	0.015	-5517.379	Yes	no	8	0.034
b	MEI	River level	eggs	0.038	-5517.379	Yes	no	10	0.068
c	MEI	month	eggs	0.001	-10361.94	Yes	no	2	0.009
c	MEI	mei_lan	eggs	0.05	-10361.94	Yes	no	11	0.082
c	MEI	mei_eln	River level	0.082	-10361.94	Yes	no	16	0.092
b	MEI	River level	plantain	0.086	-13490.46	Yes	no	17	0.091
b	MEI	mei_eln	River level	0.089	-13490.46	Yes	no	18	0.089

Key: The first VAR model included severity (9 values), the second VAR model included ENSO as a categorical variable (neutral, El Niño, La niña), and the third VAR model included two continuous values of indices for the two phases. The "mei_sev" refers to the severity variable from that ENSO index, for example, mei_sev refers to the severity categories of MEI index. Similarly, mei_lan refers to La Nina component of the index, while index mei_eln refers to El Nino of that index. River level refers to discharge of Rio Nanay.

Table 3-4: Excluded VAR models Excluded VAR models based on residual autocorrelation

VAR Model	ENSO index	A	B	pvalue	BIC	Stable?	Residual autocorrelation?
a	MEI	mei_sev	sugar	0	-3033.68	Yes	Yes (2,3)
a	MEI	month	sugar	0.001	-3033.68	Yes	Yes (2,3)
b	MEI	mei_enso	sugar	0	-4728.239	Yes	Yes (2,3)
b	MEI	month	sugar	0.001	-4728.239	Yes	Yes (2,3)
c	MEI	mei_lan	sugar	0.003	-8593.705	Yes	Yes (2,3)
c	MEI	month	sugar	0.001	-8593.705	Yes	Yes (2,3)
b	MEI	River level	plantain	0.044	-6736.038	Yes	Yes (2)
b	MEI	River level	plantain	0.017	-8661.574	Yes	Yes (2)
a	MEI	month	eggs	0.001	-3589.755	Yes	Yes(2)

Table 3-5: Results from Granger Causality tests from ONI and SOI index

Model #	VAR Model	ENSO index	A	B	pvalue	BIC	Stable?	Residual autocorrelation?
1	a	ONI	non.sig	rice	non.sig	-3002.091	Yes	no
2	b	ONI	non.sig	rice	non.sig	-4518.665	Yes	no
3	c	ONI	non.sig	rice	non.sig	-10080.58	Yes	no
10	a	ONI	month	sugar	0.001	-2807.564	Yes	no
11	b	ONI	month	sugar	0.001	-4315.659	Yes	no
12	c	ONI	month	sugar	0.001	-9851.598	Yes	no
12	c	ONI	oni_lan	sugar	0.086	-9850.598	Yes	no
19	a	ONI	river level	yucca	0.079	-b188.569	Yes	no
19	a	ONI	oni_sev	yucca	0.008	-b187.569	Yes	no
20	b	ONI	river level	yucca	0.051	-3707.557	Yes	no
20	b	ONI	oni_enso	yucca	0.000	-3707.557	Yes	no
21	c	ONI	oni_lan	yucca	0.002	-9264.888	Yes	Yes(1)
28	a	ONI	river level	eggs	0.094	-1925.69	Yes	no
28	a	ONI	month	eggs	0.002	-1925.69	Yes	no
29	a	ONI	river level	eggs	0.049	-3563.308	Yes	no
29	a	ONI	month	eggs	0.001	-3563.308	Yes	no
30	a	ONI	month	eggs	0.002	-9915.997	No	no
37	b	ONI	river level	plantain	0.043	-5079.817	Yes	no
38	b	ONI	river level	plantain	0.026	-6713.754	Yes	no
39	b	ONI	river level	plantain	0.069	-13047.59	No	no
4	b	SOI	non.sig	rice	non.sig	-2823.506	Yes	no
5	b	SOI	non.sig	rice	non.sig	-4545.499	No	no

6	c	SOI	non.sig	rice	non.sig	-10273.19	No	no
13	a	SOI	soi_sev	sugar	0.023	-2652.888	Yes	no
13	a	SOI	month	sugar	0.001	-2652.888	Yes	no
14	b	SOI	soi_enso	sugar	0.083	-4358.819	Yes	no
14	b	SOI	month	sugar	0.002	-4358.819	Yes	no
15	c	SOI	soi_lan	sugar	0.011	-10059.4	No	no
15	c	SOI	soi_month	sugar	0.001	-10059.4	No	no
22	a	SOI	river level	yucca	0.02	-2016.521	Yes	no
22	a	SOI	soi_sev	yucca	0.004	-2016.521	Yes	no
23	b	SOI	river level	yucca	0.012	-3740.331	Yes	no
23	b	SOI	soi_enso	yucca	0.011	-3740.331	Yes	no
24	c	SOI	river level	yucca	0.031	-9488.821	No	no
24	c	SOI	soi_eln	yucca	0.003	-9488.821	No	no
24	c	SOI	soi_lan	yucca	0.005	-9488.821	No	no
31	a	SOI	river level	eggs	0.034	-2255.684	Yes	no
31	a	SOI	soi_sev	eggs	0.021	-2255.684	Yes	no
31	a	SOI	month	eggs	0.001	-2255.684	Yes	no
32	a	SOI	river level	eggs	0.015	-3651.498	Yes	no
32	a	SOI	month	eggs	0.000	-3651.498	Yes	no
33	a	SOI	soi_lan	eggs	0.007	-7726.48	Yes	no
33	a	SOI	month	eggs	0.002	-7726.48	Yes	no
40	b	SOI	river level	plantain	0.024	-5409.153	Yes	no
41	b	SOI	river level	plantain	0.013	-6803.91	Yes	no
42	b	SOI	river level	plantain	0.048	-10858.37	Yes	no

Figure 3-3: Impulse Response Function of food prices by MEI index.

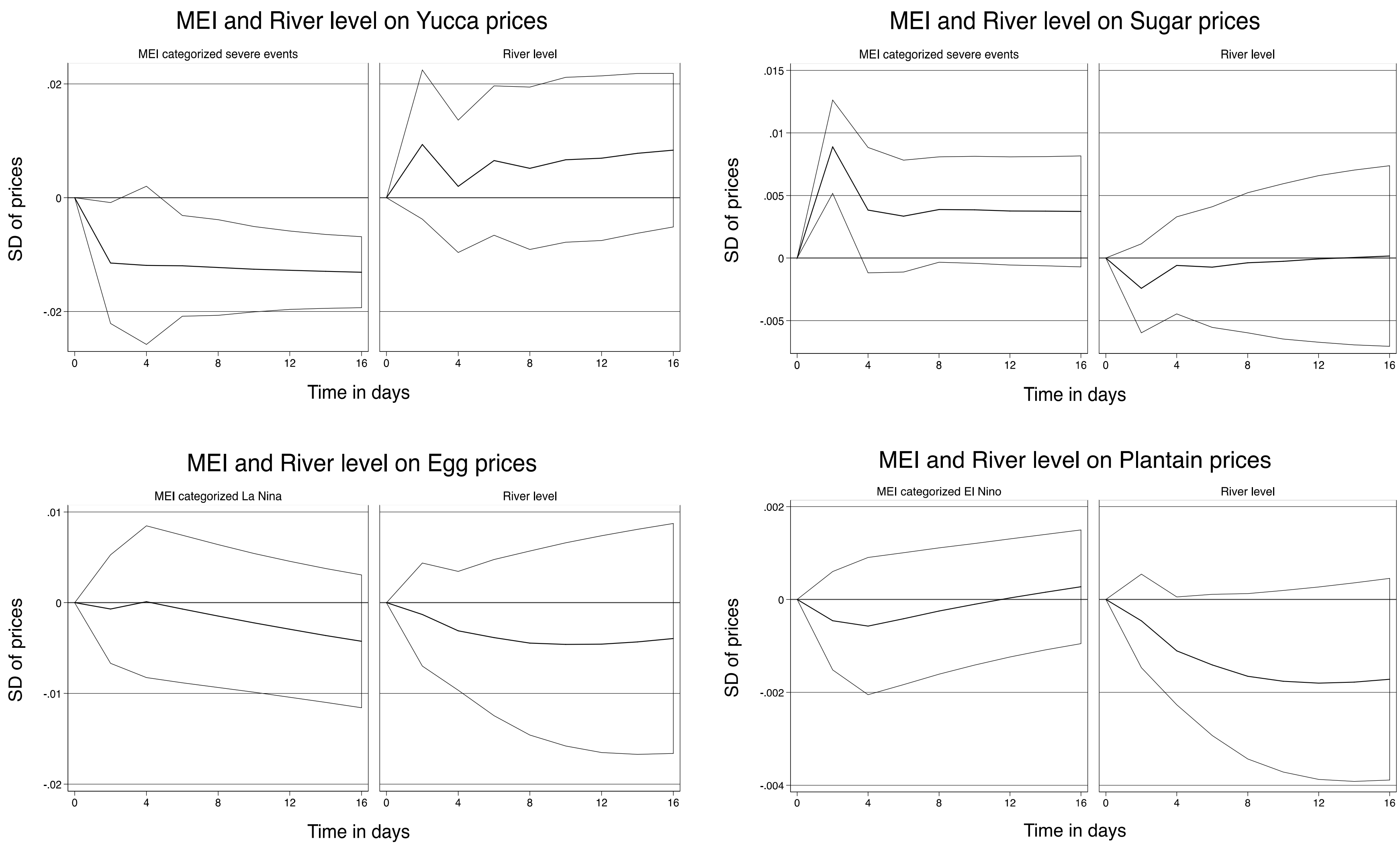
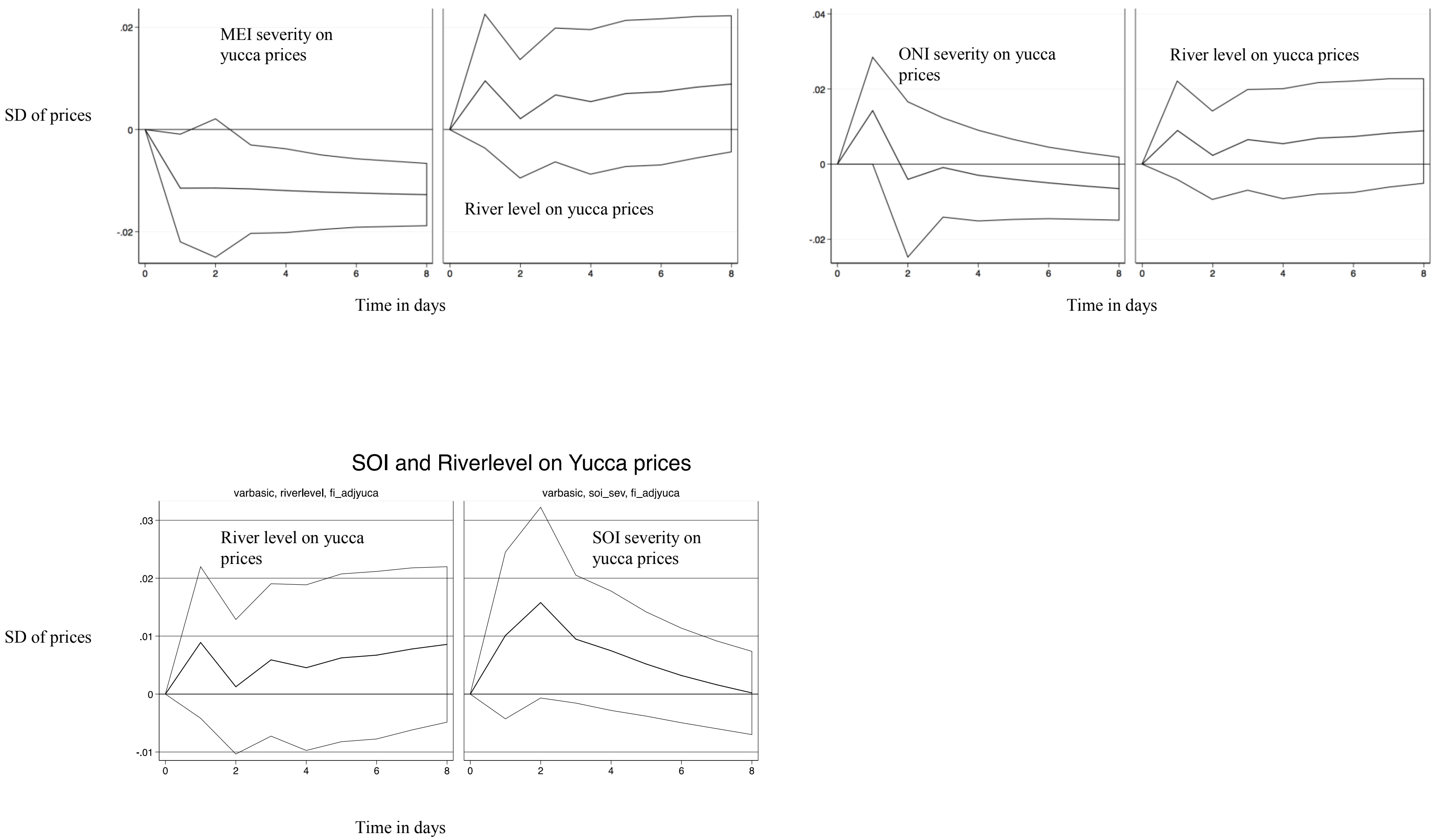


Figure 3-4: Yucca prices by MEI, ONI, and SOI index



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Chapter 4 : El Niño Southern Oscillation Affects Food Consumption, Intake, and Dietary Diversity In The Peruvian Amazon

Abstract

El Niño Southern Oscillation (ENSO) events not only affect precipation and temperature patterns in Peru, they also affect river discharge in the region. River discharge levels have a cascade effects on the economy and the nutritional status in the Peruvian Amazon because the riparian communities in this region rely on the river for food (fish), and trade (natural products, grains, and other commodities). The aim of this study is to examine the impact of ENSO exposure on: (1) frequency of food consumption patterns, (2) the amount of food consumed (g/day), and (3) dietary diversity of children 9-36 month of age located in the Santa Clara community in the Peruvian Amazon. There were reduced intakes of meal and snack items containing fish, and plantains by 24-48% whereas after adjusting for covariates. In weak La Niña, there was increased consumption meals and snacks with meat, poultry, and plantains. However, with increasing severity of La Niña, the effects were reversed, and there was reduced intake of foods containing grains, poultry, dairy, rice or sugar. Girls had a different consumption patterns associated with various ENSO events. Under a moderate El Niño, amount of fish consumption was reduced by 19 grams and under a weak La Niña, sugar intake increased by 6 grams but only for boys while decreased for girls. Despite seasonal fluctuations in the availability of fruits, vegetables and fish in this community, dietary diversity (DD) remained constant across seasons as children age. However, there were significant and negative changes in the DD under La Niña, and a modest reduction of DD score for girls under La Niña. This is the first study to show the differential effect of the ENSO on the food consumption patterns of children, especially highlighting the differences by gender, thus calling for climate sensitive nutritional

programs to intervene and ameliorate the effects of ENSO events on food consumption patterns.

Introduction

El Niño Southern Oscillation events are associated with droughts in South East Asia and in Southern Africa, floods in the Amazonian regions, and hurricanes in the Carribean and in the Gulf of Mexico (Adams et al. 1999; Adams et al. 2003; Kovats et al. 2003). The associated variabilities in crop yields are in different directions depending upon the ENSO (El Niño vs La Niña) phase, and have differential effects around the world. For example, the El Niño phase can cause torrential rainfall in coastal Peru, leading to crop failure through excess soil saturation and mudslides, even in the interior Amazon, South East Asia, Malaysia, and Indonesia crop failures occur due to reduced rainfall and drought-like conditions (Kovats 2000; Intergovernmental Panel on Climate Change 2013).

In the Peruvian Amazon, dietary intake and nutritional status are inextricably linked to the rivers, which are influenced by ENSO phases and severity (Sherman 2014). River discharge levels provide the main mediating link to the economy in the Amazon because flooding behavior determines the biogeography of aquatic, terrestrial and human settlements (Schöngart & Junk 2007). Dry season reforestation (June-November) is not only a critical element of the energy balance of the Amazon forest as an ecosystem, but it is also a period where there is increased availability of food for humans, from both forest products and fisheries (Schöngart & Junk 2007). The wet season (December-May) is the primary driver of transfer of nutrients between terrestrial and aquatic ecosystems (Schöngart & Junk 2007). It has been noted that flooding cycles have become more infrequent yet intense compared to the productive flash floods. Thus, ENSO events have cascading effects on the interconnected ecosystem, particularly on fish availability, agricultural productivity, and forest products.

In the first report, the relationship between ENSO events on the discharge of Nanay river and food prices in the Loreto Province of the Northeastern Peruvian Amazon were examined. Overall, the Multivariate ENSO Index (MEI) and Southern Oscillation Index (SOI) were the strongest predictors of river levels after adjusting for seasons ($r^2 = 0.70$). Regarding food prices, ENSO modulates prices of the key household staples -- eggs, plantains, yucca, rice and sugar -- through river discharge of the Nanay River, which is located adjacent to the households included in this study. During food price hikes, households affected by reduced access to food may alter their behavior and food consumptions patterns to maintain food security. These include adopting coping strategies such as lowering the quality and quantity of food eaten, migration, bartering, gifting, rationing, borrowing on credit, reducing non-food expenses, and increasing labor output (Brown 2014; Ruel et al. 2009). In particular, price hikes on staple foods may directly affect dietary quality, leading to a less diverse, lower quality diet and even smaller quantities of total food consumed (Bouis et al. 2011).

Study Hypothesis

This report explores how the effects of ENSO translate into changes in individual-level dietary patterns, including the amount and diversity of food consumed. The aim of this report is to (1) test whether El Niño leads to reduced frequency of meals with fish, meat, eggs, poultry, grains, rice, plantains, yucca, dairy, and sugar after adjusting for age, season, morbidity and other socioeconomic factors among children 9-36 months of age in the Peruvian Amazon (and vice versa for La Niña), (2) test whether the relationship from the first analysis was true for the amount (grams) of rice, sugar, yucca and fish consumed, and finally, (3) examine the relationship between ENSO and the dietary diversity of these children aged 9-36 months.

Methods

Study design

This analysis is nested within The Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development (MAL-ED) cohort in Peru (Yori et al. 2014). Briefly, the MAL-ED study followed a cohort of children from birth to five years, collecting data on morbidity, growth, dietary intake, cognitive development and gut enteropathy markers (MAL-ED Network Investigators 2014). Overall, 303 mother-child pairs were enrolled from December 2009 to February 2012 from the peri-urban community of Santa Clara, which is located 15km from the city of Iquitos (Yori et al. 2014). During this time, El Niño and La Niña cycles of varying severity were observed.

Of the 303 children that were enrolled, 46 moved out of the study site, four were lost-to-follow up and one child died before monthly dietary intakes were quantified beginning at nine months of age.

Key outcome variables

Monthly dietary data and recipes were collected by trained personal using the 24-hour recall methodology from caregivers of children aged 9-36 months from August 2010-September 2014. Dietary intake were collected beginning when the children turned nine months of age because the amount of non-breast milk food increases in this time period (Caulfield et al. 2014). Overall, 5,716 24-hour recalls and 19,035 recipes were recorded.

Quality control was undertaken at multiple levels: (1) though oversight by the field supervisors, which included checking recipe and ingredient codes; (2) at the data-entry level, including double data entry, confirming skip patterns, built-in checks on negative amounts, and missing data checks; and (3) by the MAL-ED cohort Data Coordinating Center, where a trained nutritionist examined meal patterns and recipes and communicated with the field staff in order to confirm or clarify questionable values.

To determine energy, macronutrient and micronutrient intakes, a MAL-ED food composition able was developed. The initial base food composition table was developed at Instituto de Investigación Nutricional (IIN, Lima Peru) by Dr. Hillary Creed de Kanashiro. Recipe analysis was conducted to develop composite recipes, and retention factors from the United States Department of Agriculture (USDA) were applied before calculating the final nutrient content per recipe (USDA 2014). For ingredients that were not found in the Peruvian food composition table, nutrient information was retrieved from the USDA and from the food composition table from the Food and Agricultural Organization (FAO, 1994). Composite recipes were created based on recipes contributed by families and were used to characterize purchased or gifted foods.

Several outcome variables were constructed from the 24-hour recalls for the three parts of this report: (1) counts describing the food items (meals or snacks) with fish, meat, eggs, poultry, grains (wheat, noodle, maize, rice), rice, plantains, yucca, or dairy consumed by the child; (2) the amounts in grams of rice, yucca, sugar and fish consumed by the child; (3) dietary diversity (DD), based on seven food groups (grains/root/tubers, dairy, legumes/nuts, meat, eggs, vitamin A rich fruits and vegetables, and other fruits and vegetables (World Health Organization 2010). In this community, the gifting of prepared food in exchange for services is common, and accordingly the field workers were instructed to write in the comment section of the 24-hour recall form if any of the food items consumed by the child had been gifted. From this information, a binary variable on gifting was created to identify such foods within each recall.

Independent variables

The main independent measure of interest was ENSO, which is captured by the MEI ENSO index, with values ranging from -3.2 to 2.6 for each month. Based on the first report where three ENSO indices on river discharge were analyzed, MEI severity variable (in particular severity variables) was identified as the most parsimonious models. Accordingly, severity of ENSO variable (9 categories indicating neutral, weak El Niño, moderate El Niño, strong El Niño, very strong El Niño, weak La Niña, moderate La Niña, strong La Niña, and very strong La Niña) was used as the main exposure variable. In addition, the model was adjusted for season using a dummy month variable.

Child-level variables included gender and birth month-year and three time-varying covariates: age, breastfeeding, and morbidity. Age was grouped in six-month categories (9-15, 16-24, 25-30, 30-36). Because breast milk intake was not quantified, a breastfed children may seem to have lower intakes from complementary foods, and this needs to be accounted for appropriately. A binary breastfeeding variable was included which indicated whether the child was still breastfed. To characterize morbidity, two variables at the monthly level were created to adjust for differences in food consumption that result from illness generally, and diarrhea in particular include (Becker et al. 1991): personal prevalence of diarrhea and of illness 30 days prior to the dietary recall. Children were considered ill on a day they had diarrhea, fever, vomiting, and cough.

Household-level factors included a validated socio-economic scale (SES) called the WAMI (Psaki et al. 2014) . This scale includes indicators of water, sanitation, and hygiene, household size, dwelling size, maternal education, and income (in USD). SES information was re-assessed every six months. Because the variances observed across multiple SES measures were similar to the baseline SES, the baseline SES form was used in the analysis (collected when the child was six months of age).

Statistical Analysis

For the first analysis, in order to evaluate the counts of food items within various food groups consumed by the child, Poisson and negative binomial regression for panel data were used. These models are frequently used to examine the associations of food consumption patterns with ecological exposures such as the neighborhood food environment (Powell & Bao 2009; An & Sturm 2012). After examining the mean and variance of the count variables, the following variables were found to be over-dispersed: dairy, yucca, sugar, and gifting. Accordingly, negative binomial regression models were utilized for these variables. Results are presented as incident rate ratios, and can be interpreted as the percent of the food item consumed (beta coefficient-1 x 100 = %) in the 24-hour recall. Models were run with and without the river level (meters) variable to examine the magnitude of attenuation due to ENSO severity. Final models were selected based on Akaike Information Criteria (AIC). Models with interaction terms added were compared to the models without interaction terms. If the models with interaction terms had a significant term and had a AIC difference of less <10 compared to the simpler models, they were selected as the final model (Burnham 2003).

For the second analysis, linear random effects (RE) regression was used to assess the association between ENSO exposure and the amounts children consumed of rice, sugar, yucca and fish. Robust standard errors were estimated to account for heteroskedasticity. In addition to controlling for the covariates from the first analysis, total energy intake reported from each recall was included in the model, for the reason that energy intake is a known confounding factor (Willett et al. 1997). For comparison purposes, tobit models with left truncation at zero were also run for the amount consumed. Generally, tobit models are not used to estimate associations with food consumption as this is a two-part decision process – first, to eat and second, to eat a certain portion size (Haines & Popkin 1988). However, in this case because the tobit models were truncated at zero, only the consumed amount was modeled, i.e. no zero intake.

Finally, for the last set of analysis, random effects were used to examine the association between dietary diversity and ENSO exposure. Again, for comparison purposes fixed effects models were estimated. Logistic and poisson models were estimated for consumption of gifted food items. Statistical significance was determined by p-value of <0.5, however p values <0.10 were also noted for trending significance. All analyses were performed in Stata version 13.1 (StataCorp 2013).

Results

Shown in Table 4-1 are the characteristics of ENSO exposure on the cohort of 252 children from nine to 36 months of age. The majority of the ENSO exposure in this cohort (as measured by the MEI index) was classified as weak and strong El Niño or La Niña, however younger age groups also have exposure to moderate El Niño and La Niña. In contrast, by the SOI index, the majority of the exposure in the cohort would be classified as La Niña, with varying severity.

The median number of dietary recall visits per child was 27 IQR (19, 28). Although the median days with diarrhea remained constant across age groups, the median number of days with illness was high with eight days per month and was reduced to four days a month as children age. The median household income of the families is USD 128 (IQR: 104, 170), and mothers on average have eight years of schooling at study enrollment. In this cohort, 75% of the children were weaned by 22 months of age, and there were no significant gender differences in age at weaning. Median monthly days with diarrhea was 0 (IQR: 0, 3) and remained constant across age groups, while the days with illness was 8 (IQR: 3, 14) at 9-15 months of age and reduced to 4 days (IQR: 0, 10) at 31-36 months of age. Average household SES score was 0.5 (IQR: 0.4, 0.6).

Food consumption

A summary of food groups consumed is presented in Table 4-2 by child age. Overall, across the age groups, children received on average two food items with rice, four food items with grains, one food item with eggs, and finally, one food item with dairy, per day. Among the animal source foods, eggs and dairy were the most commonly consumed. Poultry and meat intake increased with age. Small spikes in fish consumption were observed from June to September each year, corresponding to periods of lower river levels and increased fish availability. In contrast, poultry intakes are higher from September to January of each year. Dairy intake shows a remarkable pattern where intake spikes every three months across the years. Dietary diversity score remained constant, despite seasonal trends in the various intakes source of animal source foods (see Figure 4-1).

Shown in Table 4-3 are the model results of ENSO exposure on food items consumed after adjusting for SES, illness, energy intake and age (see supplemental Table 4-6 for the complete model covariates). Gender affected consumption patterns of rice, yucca and dairy, and accordingly interaction terms with ENSO exposure variables were included in the final models. Girls consumed more meals/snacks with rice ($p<0.01$) and dairy, but reduced meals with yucca compared to boys. However, during weak El Niño, yucca consumption increased by 59.2% for girls. There were significant reductions in meals/snacks with sugar and poultry during weak La Niña, and significant reductions in plantains during strong La Niña for girls compared to boys. Models with the diarrhea variable included showed similar results compared to the models with the illness variable, however, the illness variable was kept in the final models as a conservative estimate, which only significantly affected the meals with grain outcome.

There was a marginal -24.2% (95% CI: -41.2 to 3.9) decrease in consumption of fish under moderate El Niño conditions. Further, the model results for fish confirm the seasonal trend illustrated in Figure 4-1, where there was a 19-55% increased intake of fish from July to September during the periods of low river level, as expected. Lower SES is associated with higher intake of fish. Across the food items, there were a significant reduction in intake of plantains (-48.5%) during moderate El Niño. There was a marginal increase in intake of meals with poultry during weak El Niño. During weak La Niña, the trends are reversed with significantly increased intakes of meat (15%), poultry (17%), and plantains (19%). With increasing severity of La Niña, there is significantly reduced intake of food items containing grains, rice, sugar or dairy, while only plantains show increased intake (by 47.2%) during a strong La Niña, suggesting a possible substitution.

During the months of increased intake of fish, there were fewer meals with meat. There were no significant seasonal trends in consumption of rice or plantains. Consumption of all animal source foods other than fish and eggs was strongly and positively associated with ownership of assets, while fish, rice, plantains, and yucca consumption were associated with ownership of fewer assets. Similar trends are observed for maternal education, with higher education is associated with fewer meals with fish and more meals with grains, meat, eggs, poultry and dairy. More days with illness was significantly associated with reduced intake of meat (0.3%) only.

Amount consumed

Shown in Table 4-2 are the summary of amounts consumed (in grams) of these four food items. Grams of rice, fish and sugar increased as children aged while there were only marginal increases in the amount of yucca consumed. Rice and sugar are the mostly commonly consumed items, with up to 94.1% and 87.1% of the dietary recalls having one meal/snack with rice or sugar. The food least commonly consumed among the four (rice, yucca, sugar, fish) food items was yucca, present in only 13% of the recalls (child days). Fish consumption is reported in only 38.0% of the recalls. This is lower than might be expected for a riparian community but availability of fish is seasonal. The top five most commonly consumed fish species in this cohort include palometa (*Mylosoma duriventris*), boquichico (*Prochilodus nigricans*), bagre or flatwhiskered catfish (*Pinirampus pirinampu*), canned tuna, and tilapia (*Tilapia rendalli*).

Results from the RE and tobit models are shown in the Table 4-4. Overall, the models approach similar results (in the same direction and magnitude) except when comparing yucca and fish. The tobit model show reduced intake of fish by 19 grams/day during a moderate El Niño consistent with the first analysis on meal consumption patterns, however, random effects regression model showed increased intake of 8 grams/day during a weak El Niño.

Figure 4-2 summarizes the predicted intakes of fish, rice, sugar, and yucca under varying severity of ENSO exposure of the Tobit model, holding all other variables constant. Girls consumed 13.9 grams less of yucca compared to boys, however, this increased significantly during weak El Niño and weak La Niña (marginal significance), consistent with findings from the first analysis on frequency of meal consumption. However, there were no differences in intakes of yucca under various ENSO severities (only marginal significance of reduced intake of rice under weak El Niño). With regard to sugar intakes, tobit models indicated a higher intake (of 6 grams) consumed during a weak La Niña compared to neutral conditions. During the strong La Niña, there was increased intake of sugar (14-19 grams) in both models. Although, overall these findings for sugar and rice were not consistent results from the first analysis for severe La Niña (where there were decreased reports of food items with rice (-21%) and no differences in intake for sugar), the gender interaction term for weak La Niña for sugar in both models were consistent with first set of analysis. Tobit models for fish and yucca intake data were supportive of intake results from the first analysis for moderate El Niño and weak La Niña.

Dietary Diversity

Dietary diversity was consistent across age groups with the median consumption of 4 food groups (IQR: 3,5). The most commonly consumed food groups (in order of decreasing consumption) were grains/tubers, followed by other fruits and vegetables, meat, dairy, eggs, vitamin A-rich foods, and legumes. There were no seasonal, birth order, or income related differences in the DD score, and accordingly these were removed from the final model (see Table 4-4). ENSO variables without the severity were used in the model as these models had a lower AIC compared to models with severity variable. Only La Niña conditions were associated with a reduced DD score (0.150-0.305 in both random and fixed effect models, respectively). In the RE model, girls had a higher DD score compared to boys but reduced DD score during La Niña by 0.132 ($p<0.05$), which is consistent with the fixed effects model. Maternal education was strongly and positively associated with the DD score, and illness was marginally associated with a reduction in DD score.

Among the 5,716 dietary recalls, 22.4% of the forms indicated consumption of gifted foods. Shown in Table 4-6 are the results from logistic and poisson models on the factors associated with gifted foods. Households with girls generally had 26-43% higher frequency of gifted foods compared to boys. During a moderate El Niño, gifting increased by three fold and was higher among girls, and was significantly associated with lower socio-economic, suggesting that these practices may offset negative effects of ENSO exposure on dietary intake. Strong La Niña, conditions were associated with significantly lower number of gifted foods. Both models show consistent results with each other.

Discussion

This study aimed to explore the associations between ENSO exposure on food consumption patterns in the Peruvian Amazon. During an El Niño event, river levels are typically reduced, thus subduing the flooding patterns and reducing the productivity of the ecosystem (Schöngart & Junk 2007). In addition, due to shifts in precipitation patterns, crop productivity observed during this period are negatively affected, perhaps affecting the dietary patterns in the region. As expected, the analysis confirmed that during a moderate

El Niño as measured by the MEI index, there were reduced intakes of meal and snack items containing fish, and plantains by 24-48% even after adjusting for seasonal differences, age, morbidity, energy intake and socio-economic status. In weak La Niña, there was increased consumption of meals and snacks with meat, poultry, and plantains. However, with increasing severity of La Niña, the effects were reversed, and there was reduced intake of foods containing grains, poultry, dairy, rice and sugar. This could be attributed to the increased and intense flooding observed during La Niña events that leads to crop loss (Mäki et al. 2001). Interestingly, when there was reduced intake of staples such as grains/rice under these severe conditions, plantain consumption increased by 99%, suggesting a potential substitution. In related research on food insecurity in this community, community fieldworkers mentioned there is frequent substitution of yucca and plantains for rice during dire times. We posit that younger children are perhaps protected from these practices, hence, no differences in intakes were observed for rice, even if meal frequency is reduced as models indicated from the first analysis. This has been observed in other parts of Peru and in the Brazilian Amazon, where mothers provide "nutritional buffering" for their children, in particular for energy and protein (Piperata et al. 2013; Leonard 1991; Graham 1997). Second, gifting in this community provides an adaptive mechanism for chronic scarcity (seasonality) of food and other resources (Sherman 2014). Based on investigators observations, it has been noted that its more acceptable to send girls to other households to exchange services for food. Hence, this might be a reason why we are seeing higher percent of consumption of gifted foods among girls.

When the amounts consumed were examined, grams of fish consumed were reduced (19 grams) under a moderate El Niño, confirming the frequency of intakes from the first hypothesis. Similarly, sugar intake increased by 6 grams during a weak La Niña, again supporting the first analysis from this report. For yucca, no differences were observed in yucca intake by ENSO severity with the Tobit model consistent with first analysis. Rice intake is the only food item where there were disagreements with both models and results from the first analysis on frequency of meal consumption. Generally, the tobit models were in agreement with the findings from the first analysis compared to the random effects regression models. This is likely because tobit models assume the truncated intake at zero as an indication of latent behavior associated with food consumption pattern, i.e. the observed distribution is related to behaviors associated with eating a certain meal. When comparing the RE to the tobit models of the amount consumed, the income and sanitation score were not significantly associated with intake, whereas assets was strongly and negatively associated with intakes of fish, yucca and rice. From previous research on food security in this community, we know that consumption of yucca and canned tuna were associated with lower socio-economic status as yucca is substituted for the main staple rice, and canned tuna for fresh meat. The estimated amount of fish consumed included amounts from canned products such as canned tuna and sardines, which are ubiquitous and a cheaper option than fresh meat. Therefore, it is possible that the negative association observed with fish is due to the fact that canned fish and fresh fish are not treated separately.

There were several seasonal trends observed in food consumptions patterns, including increased intake of fish from July to September with reduced intake of poultry and meat during those months. Seasonal variation in the intake of fish was confirmed in the tobit models, where the model predicted that children consume up to 20 grams/day in the month of July. Although there was not an apparent seasonal trend in the frequency of food items of sugar consumed, there was a seasonal trend in the actual amount of sugar consumed: significantly higher intakes were observed in June, July, September, October and December. The majority of the food items that contribute sugar to the child's diet are 'refrescos', which are homemade fruit juices that contain on average 20.6 g of sugar per 100 ml cup of juice. In the dry season (June-November), there is a greater availability of fruits (particularly pineapple, star fruit, passion fruit, papaya, grape fruit, camu camu, and watermelon), thus increases in sugar consumption pattern during this period. Also, during the dry season, when the river levels are lower, there is more trade and economic activity, potentially increasing household income and hence, access to fruits.

Despite seasonal fluctuations in the availability of fruits, vegetables and fish in this community, dietary diversity remained constant across seasons as children aged with minimal difference under various ENSO exposures. This may be due to the way in which DD score is estimated. For example, although fish consumption is seasonal, it is complemented by intakes of other meat such as chicken or canned tuna, so these shifts in the type of meat within a year are not reflected in the DD score. This indicated that fluctuations in food availability and pricing during these periods may affect the ability of households to maintain their DD through substitution and gifting practices.

There are several strengths to this study. First, there were longitudinal data available on 252 children regarding dietary intakes and morbidity. Second, there were multiple modelling approaches to check the robustness of the effects of ENSO exposure on meal patterns, DD score, amounts consumed and consumption of gifted food items. Some limitations of this study include potential confounding due to secular trends in the regional food systems (distribution, introduction of new technology, etc), however, we are not aware of any new food policy or programs affecting the food intake in this community. Second, moderate El Niño and moderate La Niña occurred over very brief periods of two months total and that any associations that we have observed in the models for moderate ENSO events may not be robust.

Many regions of the world are affected by one phase of the ENSO, but Peru is affected by both phases and severity. In Ecuador, ENSO-associated floods in the first trimester of pregnancy had a lasting negative impact on child cognitive outcomes years after exposure (Rosales 2014). Previous studies in Peru have shown that El Niño increases diarrheal incidence in Lima, and reduces linear growth among children in coastal regions (Checkley et al. 2000; Danysh et al. 2014).

Analyses in this report illustrated that there was a markedly reduced intake of meals with animal source foods during moderate El Niño and severe La Niña events. Identifying meals and foods reduced under various ENSO exposure pinpoints potential pathways for nutritional interventions and humanitarian assistance. Reduction in animal source foods due to ENSO events have large implication on nutrition security of children in the Amazonian communities, especially those that rely on fish as their primary animal source, and especially since the effects of ENSO are continuous across life stages (Murray & Packham 2002). Although overall reduction in DD score under various ENSO exposures were minimal, persistent reduction in DD over life span does affect the micronutrient status of the individual, and food security of the population in this region. Further research is needed to examine how these impacts manifest in other vulnerable groups such as pregnant and lactating women.

Tables & figures:

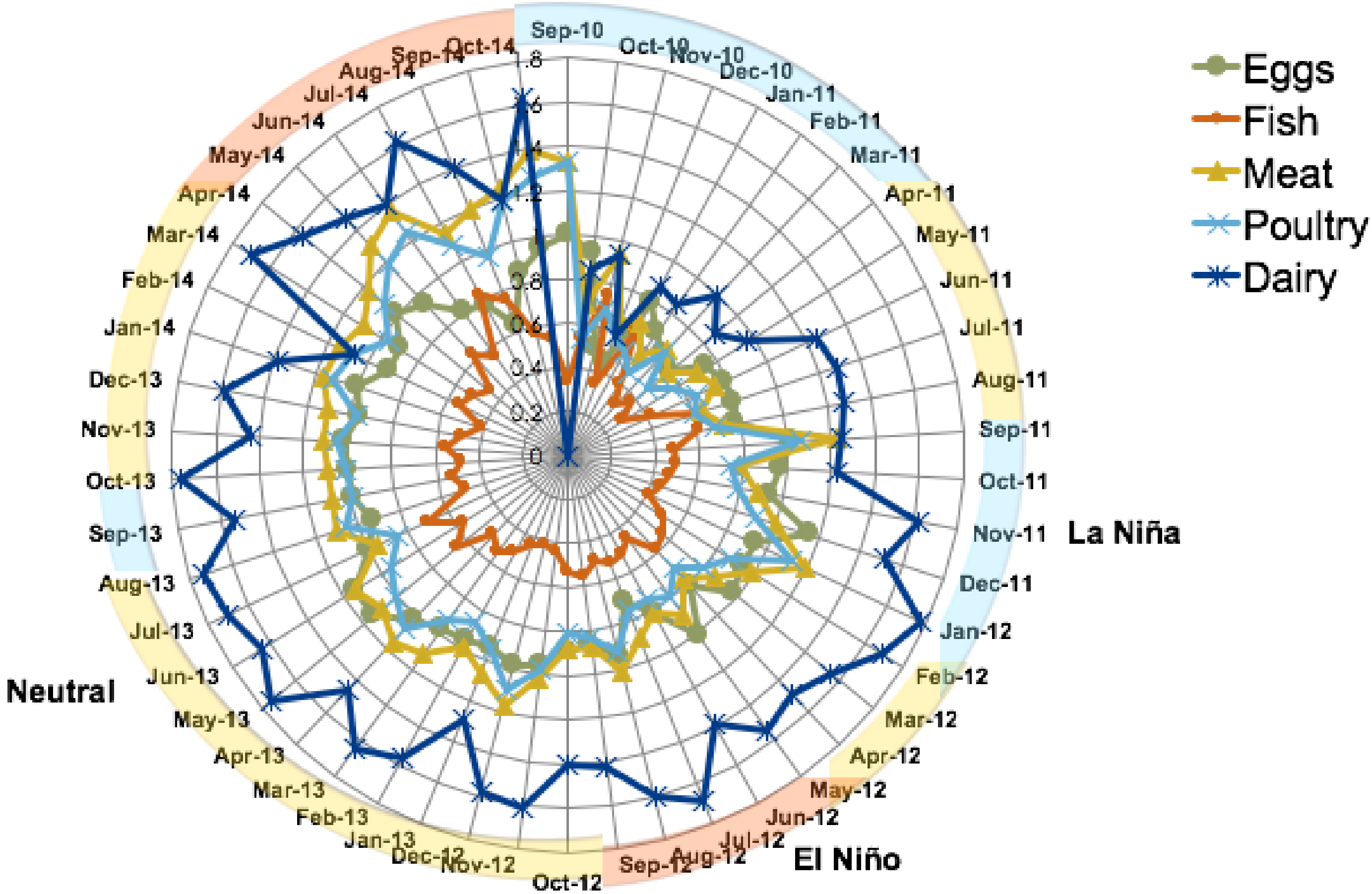
Table 4-1: Characteristics of the cohort and ENSO exposure

Age groups	9-15m	16-24m	25-30m	31-36m
N (Dietary Recalls)	1,728	1,897	1,126	965
MEI neutral (n)	850	1,173	840	671
Weak El Niño	170	203	203	257
Moderate El Niño	55	68	43	1
Weak La Niña	349	451	40	36
Moderate La Niña	72	2	0	0
Strong La Niña	232	0	0	0
SOI neutral (n)	719	1,010	784	506
Weak El Niño	0	0	9	149
Weak La Niña	468	616	332	310
Moderate La Niña	113	127	1	0
Strong La Niña	212	144	0	0
Very strong La Niña	216	0	0	0

Table 4-2: Dietary Patterns of children 9-36 months of age in the MAL-ED Peru Cohort

Age groups	9-15m	16-24m	25-30m	31-36m
Sum of food items consumed per recall				
Rice	2 (1, 2)	2 (1, 3)	2 (1, 3)	2 (2, 3)
Grains	4 (3, 5)	4 (3, 6)	4 (3, 6)	4 (3, 5)
Yucca	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)
Sugar	2 (1, 3)	2 (1, 3)	2 (1, 4)	2 (1, 4)
Eggs	1 (0, 1)	1 (0, 2)	1 (0, 1)	1 (0, 1)
Fish	0 (0, 1)	0 (0, 1)	0 (0, 1)	0 (0, 1)
Meat	0 (0, 1)	1 (0, 2)	1 (0, 2)	1 (0, 2)
Plantains	0 (0, 0)	0 (0, 0)	0 (0, 1)	0 (0, 1)
Poultry	0 (0, 1)	1 (0, 2)	1 (0, 2)	2 (1, 2)
Dairy	1 (0, 2)	1 (0, 2)	1 (0, 3)	1 (0, 2)
Grams consumed:				
Rice	24.5 (14.3, 43.0)	38.8 (23.3, 63.4)	56.5 (35.9, 89.4)	63.7 (39.0, 96.4)
Yucca	15.5 (8.0, 25.0)	25.0 (15.6, 43.7)	25.0 (18.1, 50.0)	32.2 (22.6, 58.1)
Sugar	19.1(6.4, 36.3)	36.5 (17.0, 66.3)	58.5 (27.3, 99.7)	61.6 (29.1, 106.2)
Fish	18.3 (9.5, 31.7)	29.0 (15.4, 53.4)	40.0 (22.5, 69.7)	50.0 (27.6, 88.5)
Dietary Diversity	4 (3, 5)	4 (3, 5)	4 (3, 5)	4 (3, 5)
# of Meals	4 (3,5)	5 (5,7)	6 (5,7)	5 (4, 7)

Figure 4-1: Radar plot of seasonal dietary patterns of animal source foods in children 9-36 months



Numbers in the center to the outer spoke of the wheel represent frequency of meals consumed during each dietary recall.

Table 4-3: Poisson and negative binomial model results examining ENSO exposure on food items consumed by children 9-36 months

	Poisson Regression							***Negative Binomial Regression***		
Variables	**Fish**	**Grains**	**Meat**	**Eggs**	**Poultry**	**Plantains**	**Rice**	**Dairy**	**Yucca**	**Sugar**
Neutral (MEI)				Reference					Reference	
Weak El Niño	0.992	0.974	1.087	0.953	1.114^{+}	0.963	0.993	0.93	0.824	0.958
	[0.849,1.159]	[0.921,1.030]	[0.969,1.219]	[0.842,1.078]	[0.988,1.257]	[0.791,1.172]	[0.915,1.077]	[0.832,1.039]	[0.621,1.093]	[0.888,1.034]
Moderate El Niño	0.755^{+}	1.042	1.122	0.818	1.028	0.515*	1.109	1.012	0.88	0.994
	[0.548,1.039]	[0.929,1.168]	[0.871,1.444]	[0.618,1.083]	[0.782,1.350]	[0.304,0.872]	[0.938,1.313]	[0.813,1.261]	[0.521,1.485]	[0.845,1.168]
Weak La Niña	0.930	1.01	1.150*	0.96	1.175*	1.190^{+}	0.984	1.013	0.948	1.062
	[0.792,1.091]	[0.958,1.065]	[1.029,1.286]	[0.852,1.082]	[1.046,1.320]	[0.976,1.452]	[0.909,1.066]	[0.911,1.125]	[0.701,1.282]	[0.987,1.142]
Moderate La Niña	0.995	0.827*	0.782	0.855	0.765	1.276	0.787^{+}	0.878	0.717	0.582*
	[0.619,1.599]	[0.691,0.990]	[0.508,1.203]	[0.572,1.279]	[0.483,1.214]	[0.676,2.408]	[0.593,1.043]	[0.600,1.284]	[0.255,2.017]	[0.424,0.798]
Strong La Niña	1.017	0.826*	0.943	0.910	0.944	1.992*	0.797*	0.822^{+}	0.85	0.901
	[0.766,1.352]	[0.745,0.916]	[0.745,1.193]	[0.721,1.150]	[0.733,1.215]	[1.419,2.797]	[0.679,0.937]	[0.652,1.036]	[0.467,1.547]	[0.771,1.052]
Male				Reference					Reference	
Female	0.928	1.031	1.050	1.100	1.061	1.056	1.062^{+}	1.151*	0.737*	0.996
	[0.804,1.072]	[0.980,1.084]	[0.939,1.174]	[0.975,1.240]	[0.944,1.193]	[0.883,1.263]	[0.997,1.131]	[1.007,1.316]	[0.574,0.946]	[0.909,1.091]
Weak El Niño # Female	1.045	0.954	0.91	0.938	0.879	1.113	0.961	1.05	1.592*	1.074
	[0.849,1.286]	[0.886,1.027]	[0.783,1.058]	[0.797,1.103]	[0.750,1.030]	[0.861,1.437]	[0.863,1.070]	[0.910,1.212]	[1.095,2.315]	[0.973,1.185]
Mod. El Niño # Female	1.023	0.97	0.931	0.965	0.931	1.416	0.924	1.108	0.917	1.097
	[0.662,1.580]	[0.835,1.127]	[0.669,1.295]	[0.668,1.394]	[0.650,1.332]	[0.734,2.730]	[0.742,1.152]	[0.840,1.461]	[0.418,2.013]	[0.892,1.350]
Weak La Niña # Female	1.092	0.978	0.893	1.085	0.866^{+}	0.962	0.993	1.016	1.421	0.890*
	[0.875,1.362]	[0.910,1.051]	[0.767,1.041]	[0.927,1.269]	[0.738,1.017]	[0.738,1.253]	[0.891,1.106]	[0.882,1.170]	[0.930,2.171]	[0.805,0.985]
Mod. La Niña # Female	0.63	1.064	1.141	0.82	0.91	0.304^{+}	1.021	0.963	0.98	1.307

	[0.274,1.451]	[0.821,1.379]	[0.625,2.085]	[0.446,1.507]	[0.461,1.798]	[0.0837,1.106]	[0.678,1.538]	[0.553,1.676]	[0.176,5.466]	[0.846,2.019]
Str. La Niña # Female	0.992	0.913	0.925	0.85	0.905	0.499*	0.932	0.998	1.388	0.876
	[0.641,1.535]	[0.778,1.071]	[0.654,1.309]	[0.597,1.212]	[0.624,1.314]	[0.287,0.867]	[0.730,1.191]	[0.712,1.398]	[0.568,3.393]	[0.690,1.112]
Observations	5714	5714	5714	5714	5714	5714	5714	5714	5714	5714
AIC	10608.7	22568.1	14369.5	13837.7	13817.6	8369.8	17358.3	17426.9	5290.3	19915.4
BIC	10834.8	22794.3	14595.6	14063.8	14043.7	8595.9	17584.5	17659.7	5523	20148.2
Log lik.	-5270.4	-11250.1	-7150.7	-6884.9	-6874.8	-4150.9	-8645.2	-8678.5	-2610.1	-9922.7
Chi-squared	100.1	589.1	256.5	223.6	240.9	208	276.3	912.4	96.74	1076.5

Exponentiated coefficients; 95% confidence intervals in brackets; $^{+}$ $p < 0.10$, * $p < 0.05$; Mod.: Moderate; Str.: Strong

Figure 4-2: Predicted Intake of amount consumed of fish, rice, sugar, and yucca under each ENSO phase (Tobit model)

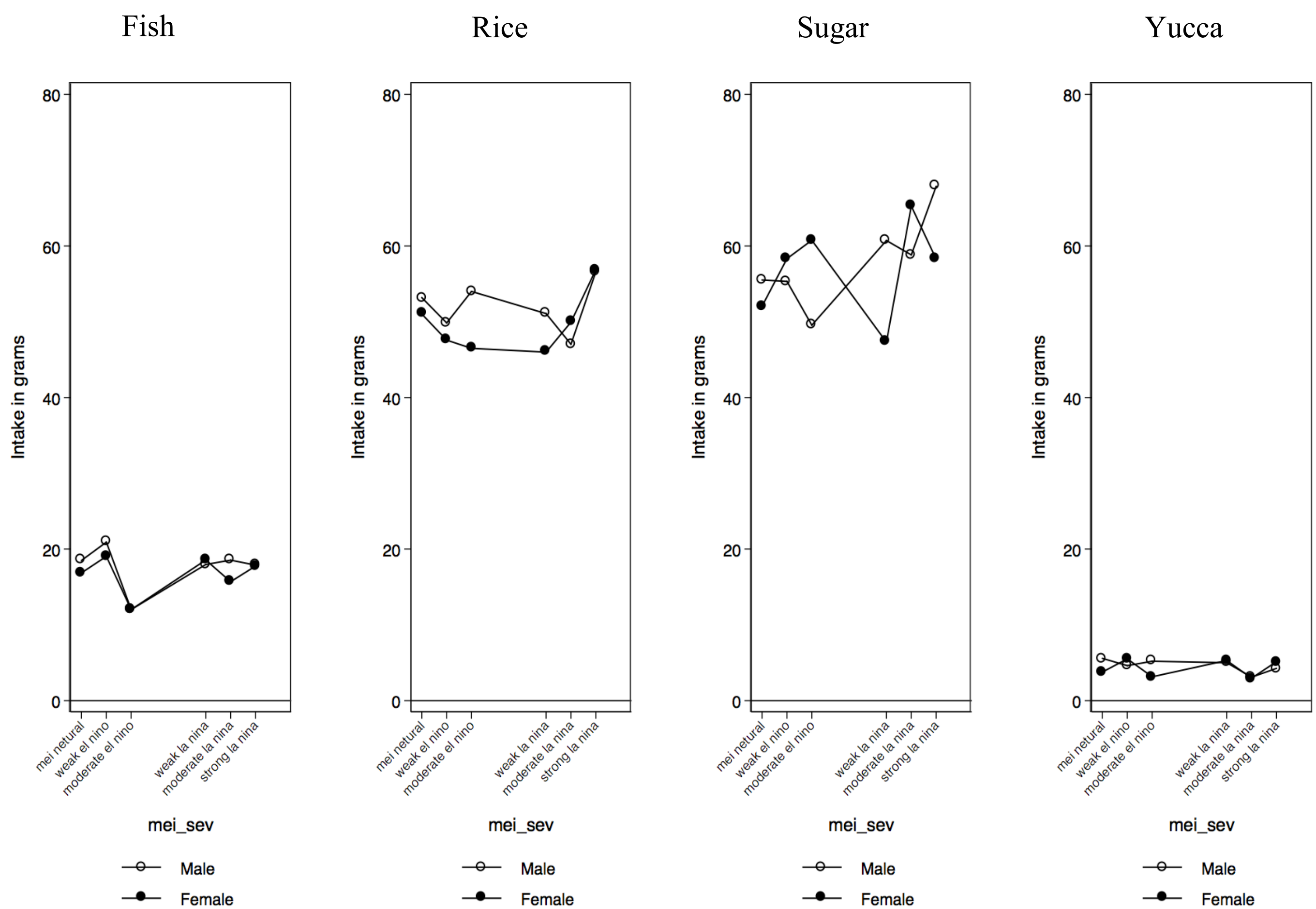


Table 4-4: Random Effects & Tobit Regression of food consumed by children 9-36 months of age

	Regression				*Tobit Regression*			
	Yucca	Fish	Rice	Sugar	Yucca	Fish	Rice	Sugar
Neutral	Reference				Reference			
Weak El Niño	1.18	8.469*	-3.797	-1.408	-7.17	5.933	-3.787+	-0.226
	[-8.648,11.01]	[0.171,16.77]	[-9.302,1.708]	[-7.620,4.805]	[-19.63,5.284]	[-2.672,14.54]	[-8.220,0.647]	[-6.214,5.761]
Moderate El Niño	15.08	-7.764	-0.0072	-9.968+	-2.712	-19.22*	0.909	-7.464
	[-3.742,33.90]	[-18.82,3.297]	[-8.108,8.094]	[-20.91,0.980]	[-27.01,21.58]	[-37.06,-1.373]	[-8.173,9.990]	[-19.72,4.796]
Weak La Niña	-3.323	-1.823	-2.417	4.296	-4.157	-1.368	-2.386	6.262*
	[-11.22,4.570]	[-8.295,4.648]	[-6.735,1.901]	[-1.422,10.01]	[-16.90,8.582]	[-9.881,7.144]	[-6.715,1.942]	[0.450,12.07]
Moderate La Niña	-19.21*	-2.254	5.482	14.89	-21.45	0.109	-7.041	4.009
	[-35.95,-2.477]	[-16.43,11.92]	[-6.734,17.70]	[-7.611,37.38]	[-64.22,21.32]	[-25.56,25.78]	[-20.09,6.004]	[-13.59,21.61]
Strong La Niña	-6.415	0.155	8.104+	19.28*	-10.17	-1.593	3.767	14.55*
	[-21.66,8.829]	[-8.199,8.509]	[-0.524,16.73]	[0.338,38.23]	[-34.36,14.03]	[-17.01,13.82]	[-4.053,11.59]	[3.908,25.20]
Male		Reference				Reference		
Female	-1.336	-1.377	-1.313	2.942	-13.92*	-2.983	-0.0253	1.355
	[-8.679,6.007]	[-7.234,4.480]	[-7.479,4.853]	[-4.261,10.15]	[-24.60,-3.231]	[-10.70,4.734]	[-5.038,4.988]	[-5.470,8.180]
Weak El Niño # Female	5.315	-3.664	0.118	6.093	21.21*	-0.227	-0.171	7.907*
	[-13.82,24.45]	[-14.33,7.005]	[-6.309,6.546]	[-2.987,15.17]	[4.757,37.66]	[-11.58,11.13]	[-6.000,5.659]	[0.0428,15.77]
Moderate El Niño # Female	-16.82	-4.064	-3.749	18.59*	-3.686	4.336	-6.131	18.04*
	[-41.62,7.973]	[-18.96,10.83]	[-13.91,6.409]	[0.0431,37.14]	[-37.77,30.40]	[-19.17,27.84]	[-18.05,5.787]	[1.885,34.20]
Weak La Niña # Female	3.001	-4.085	-2.552	-12.02*	16.67+	5.852	-3.428	-12.36*
	[-8.238,14.24]	[-12.33,4.158]	[-9.455,4.351]	[-22.71,-1.334]	[-0.992,34.32]	[-5.702,17.41]	[-9.320,2.465]	[-20.32,-4.400]
moderate La Niña # Female	18.32	2.197	-4.446	5.979	12.94	-3.368	5.82	11.83
	[-18.00,54.64]	[-17.79,22.19]	[-18.51,9.618]	[-25.18,37.14]	[-50.96,76.85]	[-41.18,34.45]	[-12.74,24.38]	[-13.33,36.98]

strong La Niña # Female	0.305	-1.738	4.03	-5.603	21.62	3.99	2.767	-6.944
	[-18.37,18.98]	[-15.64,12.17]	[-10.96,19.02]	[-30.72,19.52]	[-13.58,56.81]	[-18.75,26.73]	[-8.697,14.23]	[-22.55,8.664]

Exponentiated coefficients; 95% confidence intervals in brackets; $^{+}$ $p < 0.10$, * $p < 0.05$

Table 4-5: Model Results on Dietary Diversity Score and ENSO exposure (Random Effects and Fixed Effects Model)

	DD score (RE model)	DD score (FE model)
Neutral (MEI)	Reference	Reference
El Niño	-0.0602 [-0.163,0.0423]	-0.0216 [-0.257,0.214]
La Niña	0.150^{*} [0.0438,0.255]	0.305^{*}[0.0629,0.546]
Male	Reference	-
Female	0.218^{*} [0.0857,0.351]	-
El Niño # Female	-0.0403 [-0.194,0.114]	-0.0391[-0.194,0.116]
La Niña # Female	-0.132^{+} [-0.282,0.0184]	-0.151^{+} [-0.306,0.00341]
9-15m	Reference	Reference
16-24m	0.192* [0.102,0.283]	0.177^{*} [0.0864,0.268]
25-30m	0.0374 [-0.0751,0.150]	0.0195 [-0.0942,0.133]
31-36m	0.0137 [-0.111,0.138]	-0.00419 [-0.131,0.122]
Asset	0.0459^{*} [0.000985,0.0909]	-
Maternal Education	0.129^{*}[0.0809,0.177]	-
Illness (per 30 child days)	-0.00425^{*} [-0.00826,-0.000228]	-0.00525^{*}[-0.00951,-0.000990]
Energy intake	0.000597* [0.000497,0.000697]	0.000606^{*}[0.000506,0.000706]
Constant	2.656^{*} [2.379,2.933]	3.490^{*} [3.395,3.586]
Observations	5714	5714

95% confidence intervals in brackets; $^{+}$ $p < 0.10$, * $p < 0.05$

Table 4-6: Models results from logistic and poisson regression on factors associated with consumption of gifted foods

Variable	Logistic	Poisson
	Gift	Gift
Neutral	Reference	Reference
Weak El Niño	0.86 [0.629,1.175]	0.904[0.693,1.179]
Moderate El Niño	3.006*[1.710,5.282]	2.118*[1.357,3.304]
Weak La Niña	1.282+[0.970,1.695]	1.196 [0.953,1.500]
Moderate La Niña	0.433 [0.125,1.504]	0.472 [0.147,1.514]
Strong La Niña	0.201* [0.0834,0.483]	0.248* [0.108,0.568]
Male	Reference	Reference
Female	1.429* [1.097,1.860]	1.267* [1.050,1.529]
Weak El Niño # Female	0.802 [0.532,1.209]	0.865 [0.611,1.224]
Moderate El Niño # Female	0.337* [0.158,0.719]	0.484* [0.261,0.898]
Weak La Niña # Female	0.77 4[0.532,1.125]	0.831 [0.614,1.125]
Moderate La Niña # Female	0.351 [0.0335,3.688]	0.374 [0.0385,3.634]
Strong La Niña # Female	0.448 [0.0841,2.383]	0.454 [0.0900,2.295]
9-15m	Reference	Reference
16-24m	1.388* [1.143,1.685]	1.249* [1.065,1.466]
25-30m	1.423* [1.115,1.815]	1.272*[1.042,1.552]
31-36m	1.764* [1.358,2.291]	1.484* [1.200,1.835]
1st child	Reference	Reference
2-4 children	0.745* [0.564,0.984]	0.833+ [0.687,1.011]
5+ children	0.942 [0.635,1.396]	0.981 [0.749,1.285]
Jan	Reference	Reference
Feb	0.897 [0.646,1.244]	0.929 [0.712,1.214]
Mar	0.751 [0.533,1.057]	0.819 [0.617,1.087]
Apr	0.719+ [0.509,1.016]	0.798 [0.600,1.062]
May	0.546* [0.378,0.789]	0.641* [0.470,0.874]
Jun	0.804 [0.564,1.145]	0.852 [0.636,1.142]

Jul	0.636* [0.432,0.938]	0.725+ [0.524,1.003]
Aug	0.876 [0.621,1.234]	0.906 [0.684,1.202]
Sep	0.848 [0.615,1.169]	0.893 [0.686,1.161]
Oct	0.735+ [0.532,1.016]	0.811 [0.621,1.058]
Nov	1.099 [0.801,1.508]	1.064 [0.825,1.373]
Dec	1.604* [1.179,2.182]	1.335* [1.048,1.701]
Asset	0.908* [0.833,0.990]	0.931* [0.876,0.990]
Income	0.998* [0.997,1.000]	0.999+ [0.998,1.000]
Sanitation	1.01 [0.940,1.086]	1.006 [0.957,1.058]
Maternal Education	1.023 [0.929,1.126]	1.018 [0.953,1.089]
ill1mon	1.002 [0.992,1.012]	1.001 [0.993,1.009]
Energy intake	1 [1.000,1.000]	1 [1.000,1.000]
Observations	5714	5714
AIC	5686.9	6169.1
BIC	5919.7	6401.9
Log lik.	-2808.5	-3049.6
Chi-squared	167.4	129.7

95% confidence intervals in brackets; $^{+}$ $p < 0.10$, * $p < 0.05$

Supplement material

Table 4-7: Poisson and negative binomial model results examining ENSO exposure on food items consumed by children 9-36 months (complete list of covariates)

	Poisson Regression							***Negative Binomial Regression***		
Variables	**Fish**	**Grains**	**Meat**	**Eggs**	**Poultry**	**Plantains**	**Rice**	**Dairy**	**Yucca**	**Sugar**
Neutral (MEI)				Reference					Reference	
Weak El Niño	0.992	0.974	1.087	0.953	1.114+	0.963	0.993	0.93	0.824	0.958
	[0.849,1.159]	[0.921,1.030]	[0.969,1.219]	[0.842,1.078]	[0.988,1.257]	[0.791,1.172]	[0.915,1.077]	[0.832,1.039]	[0.621,1.093]	[0.888,1.034]
Moderate El Niño	0.755+	1.042	1.122	0.818	1.028	0.515*	1.109	1.012	0.88	0.994
	[0.548,1.039]	[0.929,1.168]	[0.871,1.444]	[0.618,1.083]	[0.782,1.350]	[0.304,0.872]	[0.938,1.313]	[0.813,1.261]	[0.521,1.485]	[0.845,1.168]
Weak La Niña	0.930	1.01	1.150*	0.96	1.175*	1.190+	0.984	1.013	0.948	1.062
	[0.792,1.091]	[0.958,1.065]	[1.029,1.286]	[0.852,1.082]	[1.046,1.320]	[0.976,1.452]	[0.909,1.066]	[0.911,1.125]	[0.701,1.282]	[0.987,1.142]
Moderate La Niña	0.995	0.827*	0.782	0.855	0.765	1.276	0.787+	0.878	0.717	0.582*
	[0.619,1.599]	[0.691,0.990]	[0.508,1.203]	[0.572,1.279]	[0.483,1.214]	[0.676,2.408]	[0.593,1.043]	[0.600,1.284]	[0.255,2.017]	[0.424,0.798]
Strong La Niña	1.017	0.826*	0.943	0.910	0.944	1.992*	0.797*	0.822+	0.85	0.901
	[0.766,1.352]	[0.745,0.916]	[0.745,1.193]	[0.721,1.150]	[0.733,1.215]	[1.419,2.797]	[0.679,0.937]	[0.652,1.036]	[0.467,1.547]	[0.771,1.052]
Male				Reference					Reference	
Female	0.928	1.031	1.050	1.100	1.061	1.056	1.062+	1.151*	0.737*	0.996
	[0.804,1.072]	[0.980,1.084]	[0.939,1.174]	[0.975,1.240]	[0.944,1.193]	[0.883,1.263]	[0.997,1.131]	[1.007,1.316]	[0.574,0.946]	[0.909,1.091]
Weak El Niño # Female	1.045	0.954	0.91	0.938	0.879	1.113	0.961	1.05	1.592*	1.074
	[0.849,1.286]	[0.886,1.027]	[0.783,1.058]	[0.797,1.103]	[0.750,1.030]	[0.861,1.437]	[0.863,1.070]	[0.910,1.212]	[1.095,2.315]	[0.973,1.185]
Moderate El Niño # Female	1.023	0.97	0.931	0.965	0.931	1.416	0.924	1.108	0.917	1.097
	[0.662,1.580]	[0.835,1.127]	[0.669,1.295]	[0.668,1.394]	[0.650,1.332]	[0.734,2.730]	[0.742,1.152]	[0.840,1.461]	[0.418,2.013]	[0.892,1.350]
Weak La Niña # Female	1.092	0.978	0.893	1.085	0.866+	0.962	0.993	1.016	1.421	0.890*
	[0.875,1.362]	[0.910,1.051]	[0.767,1.041]	[0.927,1.269]	[0.738,1.017]	[0.738,1.253]	[0.891,1.106]	[0.882,1.170]	[0.930,2.171]	[0.805,0.985]

Moderate La Niña # Female	0.63	1.064	1.141	0.82	0.91	0.304+	1.021	0.963	0.98	1.307
	[0.274,1.451]	[0.821,1.379]	[0.625,2.085]	[0.446,1.507]	[0.461,1.798]	[0.0837,1.106]	[0.678,1.538]	[0.553,1.676]	[0.176,5.466]	[0.846,2.019]
Strong La Niña # Female	0.992	0.913	0.925	0.85	0.905	0.499*	0.932	0.998	1.388	0.876
	[0.641,1.535]	[0.778,1.071]	[0.654,1.309]	[0.597,1.212]	[0.624,1.314]	[0.287,0.867]	[0.730,1.191]	[0.712,1.398]	[0.568,3.393]	[0.690,1.112]
9-15m				Reference					Reference	
16-24m	1.141*	0.960*	1.274*	1.084*	1.298*	1.065	1.04	0.973	1.298*	1.02
	[1.024,1.272]	[0.926,0.995]	[1.176,1.380]	[1.002,1.173]	[1.194,1.412]	[0.923,1.229]	[0.986,1.098]	[0.905,1.046]	[1.049,1.605]	[0.970,1.074]
25-30m	1.107	0.891*	1.290*	0.843*	1.325*	1.324*	1.014	0.783*	1.410*	0.962
	[0.968,1.265]	[0.852,0.932]	[1.169,1.423]	[0.763,0.933]	[1.194,1.469]	[1.121,1.563]	[0.949,1.084]	[0.715,0.856]	[1.093,1.819]	[0.904,1.023]
31-36m	1.099	0.823*	1.425*	0.816*	1.420*	1.503*	0.995	0.668*	1.675*	0.876*
	[0.952,1.268]	[0.784,0.865]	[1.284,1.581]	[0.732,0.910]	[1.272,1.584]	[1.263,1.788]	[0.926,1.068]	[0.606,0.737]	[1.285,2.185]	[0.819,0.937]
1st child				Reference					Reference	
2-4 children	0.968	1.032	0.882*	0.939	0.895+	0.989	0.985	1.112	1.114	1.053
	[0.835,1.123]	[0.979,1.088]	[0.785,0.992]	[0.827,1.067]	[0.791,1.012]	[0.821,1.191]	[0.924,1.050]	[0.961,1.287]	[0.871,1.426]	[0.954,1.162]
5+ children	0.851	1.029	0.794*	0.812*	0.811*	0.874	0.976	1.208+	1.106	1.066
	[0.688,1.052]	[0.954,1.109]	[0.669,0.943]	[0.676,0.977]	[0.677,0.971]	[0.669,1.143]	[0.892,1.067]	[0.979,1.490]	[0.785,1.556]	[0.925,1.228]
Jan				Reference					Reference	
Feb	1.119	0.996	0.882+	0.97	0.856*	0.99	0.98	1.031	0.917	0.984
	[0.926,1.352]	[0.937,1.059]	[0.776,1.003]	[0.847,1.110]	[0.748,0.979]	[0.798,1.228]	[0.894,1.075]	[0.911,1.168]	[0.647,1.301]	[0.904,1.071]
Mar	1.11	0.977	0.9	0.972	0.867*	0.849	0.972	1.09	0.949	0.96
	[0.917,1.343]	[0.918,1.040]	[0.790,1.024]	[0.847,1.114]	[0.756,0.994]	[0.677,1.066]	[0.886,1.067]	[0.963,1.234]	[0.667,1.350]	[0.881,1.047]
Apr	1.133	0.924*	0.896	0.976	0.904	1.024	0.936	0.997	1.079	0.999
	[0.930,1.380]	[0.866,0.987]	[0.784,1.024]	[0.847,1.124]	[0.786,1.039]	[0.816,1.284]	[0.850,1.032]	[0.875,1.136]	[0.759,1.535]	[0.915,1.091]
May	1.141	0.951	0.880+	1.068	0.862*	0.867	0.976	1.014	1.025	0.954
	[0.936,1.392]	[0.890,1.015]	[0.769,1.008]	[0.928,1.229]	[0.747,0.994]	[0.683,1.101]	[0.886,1.076]	[0.890,1.156]	[0.716,1.469]	[0.872,1.044]

Jun	1.131	0.935*	0.875+	0.978	0.837*	0.943	0.994	0.995	1.258	0.908*
	[0.926,1.382]	[0.875,0.999]	[0.763,1.003]	[0.846,1.129]	[0.725,0.967]	[0.745,1.193]	[0.902,1.096]	[0.872,1.136]	[0.889,1.780]	[0.829,0.994]
Jul	1.550*	0.921*	0.778*	0.909	0.782*	1.147	0.917	1.052	1.537*	0.904*
	[1.272,1.888]	[0.857,0.988]	[0.669,0.905]	[0.778,1.063]	[0.668,0.915]	[0.905,1.453]	[0.825,1.019]	[0.917,1.208]	[1.085,2.176]	[0.820,0.996]
Aug	1.228*	0.984	0.853*	0.928	0.846*	0.89	0.947	1.044	0.979	0.927+
	[1.010,1.493]	[0.922,1.050]	[0.745,0.976]	[0.803,1.071]	[0.734,0.974]	[0.705,1.124]	[0.859,1.044]	[0.918,1.187]	[0.686,1.399]	[0.847,1.014]
Sep	1.193+	0.953	0.924	0.969	0.927	0.983	0.986	0.932	0.97	0.986
	[0.991,1.436]	[0.896,1.013]	[0.815,1.047]	[0.848,1.107]	[0.813,1.056]	[0.792,1.221]	[0.901,1.080]	[0.822,1.056]	[0.690,1.363]	[0.907,1.072]
Oct	1.137	0.973	0.849*	0.969	0.856*	0.969	0.994	0.996	0.798	0.989
	[0.944,1.370]	[0.916,1.034]	[0.748,0.964]	[0.849,1.106]	[0.750,0.977]	[0.782,1.201]	[0.909,1.087]	[0.882,1.125]	[0.561,1.135]	[0.910,1.074]
Nov	1.101	1.017	0.916	0.983	0.93	0.886	1.007	1.083	0.699+	0.951
	[0.909,1.332]	[0.957,1.081]	[0.807,1.040]	[0.860,1.124]	[0.815,1.062]	[0.707,1.110]	[0.920,1.103]	[0.959,1.223]	[0.479,1.020]	[0.874,1.036]
Dec	0.985	0.988	0.985	1.045	0.982	0.933	1.003	1.075	0.822	1.005
	[0.811,1.197]	[0.930,1.051]	[0.870,1.115]	[0.916,1.191]	[0.863,1.118]	[0.749,1.163]	[0.916,1.098]	[0.952,1.213]	[0.573,1.178]	[0.925,1.093]
Assets	0.929*	0.996	1.040*	1.008	1.040*	0.949+	0.975*	1.079*	0.929+	1.004
	[0.889,0.972]	[0.980,1.012]	[1.003,1.078]	[0.969,1.049]	[1.001,1.081]	[0.898,1.003]	[0.956,0.994]	[1.033,1.127]	[0.861,1.002]	[0.975,1.034]
Income (USD$)	1	1.000+	1	1	1	1	1.000+	1	0.999	1
	[0.999,1.001]	[0.999,1.000]	[0.999,1.001]	[0.999,1.001]	[0.999,1.001]	[0.998,1.001]	[0.999,1.000]	[0.999,1.001]	[0.997,1.000]	[0.999,1.000]
Maternal Education	0.929*	1.018+	1.051*	1.042+	1.056*	0.993	1.009	1.112*	1.013	0.998
	[0.882,0.979]	[1.000,1.037]	[1.009,1.095]	[0.998,1.088]	[1.012,1.103]	[0.930,1.060]	[0.987,1.032]	[1.057,1.169]	[0.930,1.102]	[0.964,1.034]
Illness	0.999	1.003*	1.001	0.998	1.002	0.997	1	1.002	0.994	1.002
	[0.994,1.004]	[1.001,1.004]	[0.997,1.005]	[0.994,1.002]	[0.998,1.006]	[0.990,1.003]	[0.997,1.003]	[0.998,1.006]	[0.984,1.004]	[0.999,1.004]
Energy	1.000*	1.000*	1.000*	1.000*	1.000*	1.000*	1.000*	1.001*	1.000+	1.001*
	[1.000,1.000]	[1.000,1.000]	[1.000,1.000]	[1.000,1.000]	[1.000,1.000]	[1.000,1.000]	[1.000,1.000]	[1.001,1.001]	[1.000,1.000]	[1.000,1.001]
Observations	5714	5714	5714	5714	5714	5714	5714	5714	5714	5714
AIC	10608.7	22568.1	14369.5	13837.7	13817.6	8369.8	17358.3	17426.9	5290.3	19915.4
BIC	10834.8	22794.3	14595.6	14063.8	14043.7	8595.9	17584.5	17659.7	5523	20148.2

Log lik.	-5270.4	-11250.1	-7150.7	-6884.9	-6874.8	-4150.9	-8645.2	-8678.5	-2610.1	-9922.7
Chi-squared	100.1	589.1	256.5	223.6	240.9	208	276.3	912.4	96.74	1076.5

Table 4-8: Random Effects & Tobit Regression of food consumed by children 9-36 months of age

	Regression				*Tobit Regression*			
	Yucca	Fish	Rice	Sugar	Yucca	Fish	Rice	Sugar
Neutral	Reference				Reference			
Weak El Niño	1.18	8.469*	-3.797	-1.408	-7.17	5.933	-3.787^{+}	-0.226
	[-8.648,11.01]	[0.171,16.77]	[-9.302,1.708]	[-7.620,4.805]	[-19.63,5.284]	[-2.672,14.54]	[-8.220,0.647]	[-6.214,5.761]
Moderate El Niño	15.08	-7.764	-0.0072	-9.968^{+}	-2.712	-19.22*	0.909	-7.464
	[-3.742,33.90]	[-18.82,3.297]	[-8.108,8.094]	[-20.91,0.980]	[-27.01,21.58]	[-37.06,-1.373]	[-8.173,9.990]	[-19.72,4.796]
Weak La Niña	-3.323	-1.823	-2.417	4.296	-4.157	-1.368	-2.386	6.262*
	[-11.22,4.570]	[-8.295,4.648]	[-6.735,1.901]	[-1.422,10.01]	[-16.90,8.582]	[-9.881,7.144]	[-6.715,1.942]	[0.450,12.07]
Moderate La Niña	-19.21*	-2.254	5.482	14.89	-21.45	0.109	-7.041	4.009
	[-35.95,-2.477]	[-16.43,11.92]	[-6.734,17.70]	[-7.611,37.38]	[-64.22,21.32]	[-25.56,25.78]	[-20.09,6.004]	[-13.59,21.61]
Strong La Niña	-6.415	0.155	8.104^{+}	19.28*	-10.17	-1.593	3.767	14.55*
	[-21.66,8.829]	[-8.199,8.509]	[-0.524,16.73]	[0.338,38.23]	[-34.36,14.03]	[-17.01,13.82]	[-4.053,11.59]	[3.908,25.20]
Male	Reference				Reference			
Female	-1.336	-1.377	-1.313	2.942	-13.92*	-2.983	-0.0253	1.355
	[-8.679,6.007]	[-7.234,4.480]	[-7.479,4.853]	[-4.261,10.15]	[-24.60,-3.231]	[-10.70,4.734]	[-5.038,4.988]	[-5.470,8.180]
Weak El Niño # Female	5.315	-3.664	0.118	6.093	21.21*	-0.227	-0.171	7.907*
	[-13.82,24.45]	[-14.33,7.005]	[-6.309,6.546]	[-2.987,15.17]	[4.757,37.66]	[-11.58,11.13]	[-6.000,5.659]	[0.0428,15.77]

Moderate El Niño # Female	-16.82	-4.064	-3.749	18.59*	-3.686	4.336	-6.131	18.04*
	[-41.62,7.973]	[-18.96,10.83]	[-13.91,6.409]	[0.0431,37.14]	[-37.77,30.40]	[-19.17,27.84]	[-18.05,5.787]	[1.885,34.20]
Weak La Niña # Female	3.001	-4.085	-2.552	-12.02*	16.67+	5.852	-3.428	-12.36*
	[-8.238,14.24]	[-12.33,4.158]	[-9.455,4.351]	[-22.71,-1.334]	[-0.992,34.32]	[-5.702,17.41]	[-9.320,2.465]	[-20.32,-4.400]
moderate La Niña # Female	18.32	2.197	-4.446	5.979	12.94	-3.368	5.82	11.83
	[-18.00,54.64]	[-17.79,22.19]	[-18.51,9.618]	[-25.18,37.14]	[-50.96,76.85]	[-41.18,34.45]	[-12.74,24.38]	[-13.33,36.98]
strong La Niña # Female	0.305	-1.738	4.03	-5.603	21.62	3.99	2.767	-6.944
	[-18.37,18.98]	[-15.64,12.17]	[-10.96,19.02]	[-30.72,19.52]	[-13.58,56.81]	[-18.75,26.73]	[-8.697,14.23]	[-22.55,8.664]
9-15m		Reference				Reference		
16-24m	3.587	6.213*	4.862*	-6.649*	11.02*	11.36*	5.300*	-5.991*
	[-3.851,11.02]	[1.985,10.44]	[1.569,8.155]	[-11.28,-2.015]	[2.234,19.80]	[5.616,17.11]	[2.405,8.195]	[-9.906,-2.076]
25-30m	3.692	14.20*	15.34*	-0.0921	14.34*	13.64*	14.48*	-1.477
	[-7.531,14.91]	[7.481,20.92]	[9.711,20.97]	[-6.600,6.416]	[3.671,25.01]	[6.490,20.79]	[10.82,18.14]	[-6.428,3.473]
31-36m	8.886	20.24*	19.53*	-3.909	22.00*	13.03*	19.10*	-6.258*
	[-2.653,20.43]	[12.80,27.69]	[12.33,26.73]	[-12.09,4.269]	[10.64,33.36]	[5.300,20.75]	[15.13,23.06]	[-11.63,-0.887]
1st Child		Reference				Reference		
2-4 Children	4.601	-4.41	1.373	1.278	4.342	-2.701	0.872	2.463
	[-1.437,10.64]	[-10.05,1.225]	[-3.282,6.028]	[-5.912,8.469]	[-6.464,15.15]	[-10.69,5.288]	[-4.507,6.251]	[-4.863,9.788]
5+ Children	0.808	-3.753	3.95	4.247	3.18	-7.976	3.858	6.298
	[-7.127,8.743]	[-12.19,4.682]	[-7.065,14.96]	[-4.570,13.06]	[-12.06,18.42]	[-19.45,3.502]	[-3.934,11.65]	[-4.316,16.91]
Jan	0	0	0	0	0	0	0	0
Feb	4.672	-3.24	-2.642	1.392	-0.382	0.509	-2.354	0.237
	[-5.714,15.06]	[-12.66,6.177]	[-6.740,1.455]	[-3.398,6.182]	[-15.04,14.28]	[-9.325,10.34]	[-7.289,2.581]	[-6.425,6.900]
Mar	6.641	-9.520+	-0.685	8.235*	-0.265	3.479	-0.296	6.673+
	[-3.565,16.85]	[-19.14,0.0982]	[-5.169,3.798]	[2.113,14.36]	[-15.18,14.65]	[-6.433,13.39]	[-5.300,4.708]	[-0.0818,13.43]
Apr	8.407	-3.993	-2.722	4.909+	7.702	2.951	-1.436	5.65

	[-4.422,21.24]	[-15.38,7.391]	[-7.797,2.353]	[-0.874,10.69]	[-7.388,22.79]	[-7.394,13.30]	[-6.654,3.782]	[-1.382,12.68]
May	-3.295	-12.72*	1.595	4.279	2.431	-2.898	2.462	1.869
	[-15.27,8.677]	[-23.73,-1.701]	[-3.390,6.580]	[-1.787,10.35]	[-12.93,17.79]	[-13.36,7.567]	[-2.810,7.733]	[-5.262,8.999]
Jun	0.999	-10.48*	6.354*	7.677*	10.19	-0.977	6.723*	4.288
	[-12.79,14.78]	[-20.93,-0.0331]	[0.794,11.91]	[1.633,13.72]	[-4.976,25.36]	[-11.51,9.553]	[1.410,12.03]	[-2.895,11.47]
Jul	1.675	0.17	0.45	7.152*	17.94*	20.24*	0.818	4.228
	[-9.339,12.69]	[-11.37,11.71]	[-4.715,5.614]	[0.450,13.85]	[2.232,33.66]	[9.343,31.14]	[-4.842,6.478]	[-3.405,11.86]
Aug	-6.991	-9.340+	-0.976	5.944+	0.0263	5.512	0.479	2.807
	[-16.51,2.530]	[-19.06,0.377]	[-5.674,3.722]	[-0.465,12.35]	[-15.27,15.33]	[-4.750,15.77]	[-4.749,5.708]	[-4.246,9.861]
Sep	-2.032	-4.183	-4.230*	7.071*	0.771	3.339	-2.413	7.073*
	[-11.60,7.536]	[-14.16,5.796]	[-8.353,-0.106]	[2.569,11.57]	[-13.72,15.26]	[-6.404,13.08]	[-7.320,2.494]	[0.464,13.68]
Oct	6.865	-6.251	-1.557	7.830*	-3.334	1.542	-0.811	7.714*
	[-10.20,23.93]	[-15.15,2.648]	[-5.557,2.443]	[2.966,12.69]	[-17.94,11.27]	[-8.139,11.22]	[-5.682,4.060]	[1.153,14.28]
Nov	1.062	-6.087	-1.612	2.826	-11.44	-0.0702	-0.819	1.351
	[-10.18,12.30]	[-14.39,2.214]	[-5.955,2.730]	[-3.015,8.666]	[-26.82,3.945]	[-9.951,9.810]	[-5.764,4.126]	[-5.330,8.032]
Dec	9.66	-5.61	-2.746	5.763*	-3.782	-2.64	-0.752	5.028
	[-4.285,23.61]	[-16.61,5.392]	[-6.626,1.133]	[0.606,10.92]	[-18.63,11.06]	[-12.51,7.227]	[-5.660,4.155]	[-1.598,11.65]
Assets	-0.0513	-0.854	-1.911*	-0.0898	-3.179+	-3.544*	-2.223*	-0.427
	[-2.134,2.031]	[-2.464,0.756]	[-3.765,-0.0564]	[-2.342,2.162]	[-6.515,0.156]	[-6.011,-1.077]	[-3.887,-0.559]	[-2.691,1.837]
Income	0.0559*	0.00456	0.00552	0.00234	-0.0329	-0.0209	0.00331	0.00168
	[0.0204,0.0914]	[-0.0230,0.0321]	[-0.0292,0.0402]	[-0.0345,0.0392]	[-0.0990,0.0333]	[-0.0700,0.0282]	[-0.0299,0.0365]	[-0.0436,0.0469]
Sanitation	-2.721*	0.507	-0.555	-0.486	-1.795	-0.423	-0.459	-0.52
	[-4.202,-1.241]	[-1.059,2.072]	[-2.175,1.065]	[-2.055,1.084]	[-4.617,1.027]	[-2.497,1.652]	[-1.853,0.936]	[-2.419,1.379]
Maternal Education	-4.475*	-2.702*	-0.181	-0.898	-1.527	-3.526*	-0.294	-0.498
	[-7.239,-1.712]	[-4.609,-0.794]	[-2.524,2.162]	[-3.139,1.342]	[-5.253,2.198]	[-6.294,-0.757]	[-2.165,1.577]	[-3.044,2.048]
Illness	-0.0308	-0.137	-0.208*	-0.0712	-0.198	-0.00471	-0.236*	-0.0766
	[-0.443,0.381]	[-0.355,0.0822]	[-0.395,-0.0215]	[-0.245,0.102]	[-0.624,0.229]	[-0.294,0.285]	[-0.384,-0.0873]	[-0.277,0.124]

Energy intake	0.0168*	0.0207*	0.0305*	0.0720*	0.0109*	0.0195*	0.0334*	0.0757*
	[0.00772,0.0258]	[0.0138,0.0276]	[0.0252,0.0359]	[0.0622,0.0817]	[0.00364,0.0182]	[0.0144,0.0245]	[0.0307,0.0360]	[0.0722,0.0793]
Constant	23.33*	38.77*	28.69*	-8.383	-74.90*	-11.76	24.17*	-19.70*
	[4.708,41.95]	[24.36,53.19]	[16.84,40.54]	[-23.11,6.345]	[-101.4,-48.36]	[-30.92,7.391]	[11.79,36.55]	[-36.54,-2.860]

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Chapter 5 : El Niño Southern Oscillation affects girls' nutrient intakes and adequacies in the Peruvian Amazon

Abstract

El Niño Southern Oscillation (ENSO) is a naturally occurring climate phenomenon that causes inter-annual variability in precipitation, temperature and river discharges in the Peruvian Amazon. These environmental shifts under two different ENSO phases (El Niño and La Niña) cause large differences in crop productivity and food prices. Although, the impact of ENSO on food prices has been studied, very little is known how these effects translate to individual's nutritional security. The aim of this study is to examine the impact of the ENSO exposure on nutrition among children in a longitudinal follow up of a birth cohort in the Peruvian Amazon. Overall, 5,714 dietary recalls were collected from 252 children from 2010 to 2014, where there exposures to both El Niño and La Niña. Nutrient intakes were quantified from these recalls, and adequacy was estimated by breastfeeding status using the UN Recommended Nutrient Intakes. Overall, non-breastfed children showed lower adequacy compared to breastfed children. Most children were adequate for vitamin C, vitamin B12, and vitamin A (only among breastfed children). Although exposure to La Niña increased energy by 85 kcal, girls consumed 89-112 Kcals less than boys, after adjusting for weight, socio economic status, age, parity, and breast feeding. The differences in gender, were also observed in macronutrient intakes (especially animal source protein), micronutrient intakes and adequacy. In a resource limited setting like the one presented in this analyses, climate variations affect food procuring strategies that appear to negatively affect girls. These results have large implications on nutritional policies and programs in Peru.

Introduction

Climate is an intrinsic determinant of agricultural productivity and consequently, plays an integral role in food prices and dietary patterns among humans. Previous studies have investigated these linkages by measuring the impact of seasonality on dietary intakes among children and women (Brown et al. 1982b; Abdullah and Wheeler 1985; Bates et al. 1994; Ndekha et al. 2000; Graham 2003; Schulze et al. 2003; Faber and Laubscher 2008; Chen et al. 2010; Becquey et al. 2011; Arsenault et al. 2014). The common themes in these studies are the reduction of grain and vegetable intakes in pre-harvest as compared to post-harvest seasons due to differences in food production resulting from the seasonal change in temperature and rainfall. Also, there is a reduction in consumption of animal source foods due to limited livelihood activities in the pre-harvest season, and a shift in food expenditure towards energy-dense foods to maintain energy needs rather than nutrient-dense foods such as fruits, flesh meat, and vegetables.

In the Peruvian Amazon, there are added layers of complexity, which include large-scale climate phenomena (El Niño Southern Oscillation [ENSO]) and local ecological factors (river ecosystems), and these lead to complicated seasonal dimensions in food consumption patterns. The river ecosystems drive the food economy as it affects crop productivity, food prices, food transportation, fish availability, and more importantly, livelihood activities, which are dependent on natural resources.

Previously, we illustrated the impact of ENSO on river flow, and how both of these environmental factors influence prices of locally produced food, such as yucca and plantains. In a second report, we illustrated that consumption of meals with animal source foods (such as fish and dairy), grains, and plantains were significantly reduced among children during severe ENSO phases, even after adjusting for season, age, energy intake and socio-economic status. In particular, gender differences in intake of certain foods such as yucca, and dairy were observed; Gender differences became prominent in La Niña phases when girls had lower consumption of meals/snacks with poultry, plantains and/or sugar, and during weak El Niño, the consumption of yucca increased.

Animal source foods (ASF) such as meat, fish, poultry, eggs, and dairy are the only sources of vitamin B-12, hence any reduction in ASF may lead directly to anemia, weight loss and in extreme cases, neuropathy (Allen 2003; Murphy and Allen 2003). Reduction in ASF consumption has important implications for children, particularly for their long-term growth and cognitive development, as the foods are also important sources of zinc and iron. A national-level study in Indonesia (another geographic location affected by ENSO events) demonstrated that reductions in household expenditures for animal source protein after a food price crisis led to greater odds of stunting among children under five years of age (Sari et al. 2009). Because ASF consumption is responsive to changes in prices and household expenditures, we would expect this to be affected during periods of weather shocks such as severe ENSO events.

This is the final report of the project exploring linkages between climate, ecology, food prices and dietary intake the Peruvian Amazon. The objective of this report is to examine the adequacy of nutrient intake of young children under various ENSO conditions in the Peruvian Amazon. In particular, after controlling for socio economic factors, age, gender, birth order, morbidity, and season, we hypothesize that periods of weather shocks will be associated with lower energy and protein, and lower nutrient adequacy ratios for iron, zinc, calcium, vitamin A, vitamin C, vitamin B12, and folate. These associations will be stronger especially under severe ENSO phases.

Methods

Study design

This study utilizes data from The Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development (MAL-ED) birth cohort study, which was initiated in Iquitos, Peru in 2009 (Yori et al., 2014). The cohort enrolled 303 mother-child pairs from three towns located 15 kilometers from the City of Iquitos. Since the start of the birth cohort study, there have been severe La Niña conditions between July 2010- May 2011, weak La Niña conditions between October 2011-April 2012, weak El Niño conditions between July-October 2012 and July-November 2014, and a few brief episodes of moderate ENSO of both phases in 2011 and 2012, as gauged by the Multivariate ENSO Index (MEI).

In this birth cohort, there was intensive data collection to capture information on child morbidity, dietary intake, anthropometry, cognitive measures, gut biomarkers and household food security & economic status (MAL-ED Network Investigators 2014). Because of the longitudinal follow-up of children up to 36 months of age over a period of 28 months, this study is uniquely situated to test the hypotheses that ENSO exposures modulate dietary patterns, leading to differences in the nutrient intake adequacy of children.

Key outcome variables

Starting at nine months of age dietary intake using the 24-hour recall method was collected monthly used common utensils and food models developed for the study. To determine energy, macronutrient and micronutrient intakes, food composition table (FCT) was developed for the MAL-ED Peruvian dietary intakes. MAL-ED FCT utilized the base FCT developed at Instituto de Investigación Nutricional (IIN, Lima Peru) by Dr. Hillary Creed de Kanashiro. Retention factors from the United States Department of Agriculture (USDA) were applied before calculating the final nutrient content per recipe (USDA 2014). For ingredients that were not found in the MAL-ED or the IIN FCTs, nutrient information was obtained from the USDA and from the food composition table from the Food and Agricultural Organization (FAO, 1994). From this, energy (kcal), protein (g), animal source protein (g), protein from meat/fish/poultry (g), iron (mg), iron from meat/fish/poultry (mg), zinc (mg), folate (µg), vitamin A (µg per retinol equivalents [RE]), vitamin B-12 (µg), calcium (mg), and vitamin C (mg) were estimated. Amounts of the nutrients consumed were summarized for each day from all non-breast milk meals and snacks.

To evaluate the quality of the dietary intake, Nutrient Adequacy Ratios (NAR) (intake / Recommended Nutrient Intake (RNI) for that age) were created for all of the nutrients except for energy, protein, and iron (mg) from meat/fish/poultry (Food and Agriculture Organization of the United Nations. 2002). In this cohort, the median age at weaning was 18 months. Because the nutrients obtained from breast milk were not quantified, the requirements were adjusted accordingly for children who had breast milk in the diet based on the estimated amount of nutrient intake in the breast milk. The remaining gap between nutrient values from breast milk and the recommended nutrient intake (RNI) was treated as their adjusted RNI (World Health Organization 1998). The adjusted RNIs for breastfed children, and RNIs for non-breastfed children are shown in Supplementary Table 5-9.

Two month moving averages of each of the nutrient variables were estimated to parallel the construction of the MEI index and to reduce intra-child variability in dietary intake. The first observation for the children began at ten months of age, which included the nutrient information from dietary recall at 9 months of age. Overall, 5,716 recalls were collected from 9-36 months. There were 16 recalls that didn't have a recall in the past month; these were treated as missing for the moving average summary. In addition, 256 recalls were collected at the 9th month counted towards the moving average for the 10th month (252 unique children, with two replicates of 24 hour recalls recorded within the first month). Finally, one of the dietary recall was missing the corresponding morbidity information so this recall was not included in the analysis. The final sample size for the analysis was 5,443 moving average observations from 252 children, summarized from 5,699 recalls.

Independent variables

The main environmental exposures of interest are the ENSO conditions as measured by the MEI index (Klaus, 2016). MEI index values are calculated bimonthly and are normalized components of sea level pressure, sea surface temperature, wind flow, surface air temperature, and cloud density. Bimonthly values are assigned to the lead month, i.e., values from December to January are assigned to January. In addition, a variable to represent season was added to the model to adjust for any seasonal differences in river level, livelihood activities, and food economy.

At the household level, indicators of socioeconomic status were included in the model using an index called the WAMI (Psaki et al. 2014). WAMI consists of improved access to water and sanitation services, an asset score (owning bank account, mattress, table/bench, chair, refrigerator, and having a separate room for a kitchen, and household density of less than 2 per room), maternal education (years of schooling / 2), and monthly income in USD (Psaki et al. 2014).

Child-level variables included birth order, gender, age (categorized into six-month groups), breastfeeding status, weight (kg) and energy intake (kcal/day). Birth order was defined as follows: first born, 2nd - 4th born, and 5th + born. Breastfeeding status was ascertained during the twice weekly nutrition surveillance visits in which mothers were queried on the child's diet in the previous 24 hours (Caulfield et al. 2014; Lee et al. 2014). Based on this information, a binary variable for the presence of breast milk in the diet was created for the analysis. Age at complete weaning was also identified. Child morbidity information was summarized also from the twice-weekly surveillance visits in which the caregivers were queried about child's diarrhea, vomiting, cough, and fever. Two personal prevalence variables for days with diarrhea and days with any illness (includes all symptoms) in the preceding 30 days of the dietary recall were estimated. Weight was measured monthly using Seca baby scale by trained field staff and was recorded to the nearest 0.01 kg.

Statistical Analysis

Linear random effects regression models were used to evaluate the associations between ENSO exposures and nutrient intake and adequacies (see Table 5-1 for the summary of statistical analyses). Shown in Table 5-1 are the five models undertaken in this study, which included: (1) energy intake (2) macronutrient intake, (3) micronutrient intake, (4) NAR (not truncated at 1.0) and (5) NAR bounded at 1.0. Random intercepts were included for each child. Robust standard errors were estimated in all models to account for correlated intakes within a child, and for heteroskedasticity. In order to check the robustness of the inferences, fixed effects models were also estimated to compare the coefficients' magnitude and direction. Because we saw differences by gender as noted in the earlier report on meal patterns and amounts of food consumed, gender and main exposure interaction terms were tested.

We followed the standard multivariate approach to adjusting for energy. Energy intake is treated as a precision variable, and was added to the model for several reasons (Willett et al. 1997). First, adjusting for energy also accounts for any body size differences resulting from any previous ENSO exposure that may affect current intake. Second, adjusting for energy focuses on nutrient intake irrespective of energy intake so any observed differences in nutrient intake can be accurately attributed to ENSO exposure, rather than to the total amount of food. Birth month and year were also added to the model to account for any previous ENSO exposure in utero or before nine months of age. T-tests were used to examine the statistical difference between intakes by breastfeeding status. P-values of <0.05 was considered statistically significant, and p-values <0.10 were noted for trending significance. All analyses were performed in Stata version 13.1 (StataCorp 2013).

Results

Among the 303 children that were enrolled in the birth cohort, 46 moved out of the study site, four were lost- to-follow up before 9 months of age and one child died. Out of 252 children included in the analysis, 45.6% were female, and 38.9% were first-born (Table 5-

2). The median number of assets owned by these households were five (IQR: 4, 6). The most commonly owned items included: a television, table, chair, mattress, and a separate room for the kitchen. On average, mothers had eight years of education.

In Table 5-3, the median nutrient intakes and median prevalence of adequacy ratios are presented for each age group by breastfeeding status. There are significantly higher intakes of nutrients among non-breastfed (NBF) children, especially macronutrients and in particular for the younger age groups. However, when comparing NARs, vitamin A, C, and folate show lower adequacy among NBF groups as compared to the breastfed (BF) groups, especially for the 9-15 and 16-24 age groups. There were greater differences in energy and macronutrient intakes by breastfeeding status in the 16-24 age group compared to the 9-15 months age group. For example, there was only a 12-gram difference in carbohydrate intake among the breastfed 9-15 months age group, but there was a 41 gram difference by breastfeeding status in the 16-24 month age group. On average, 54-65% of the overall protein intakes was from animal source foods, and this is consistent across age groups and breastfeeding status.

Shown in Figure 5-1, is a heat map of nutrition adequacy ratios by breastfeeding status and season. The green color indicates that the median NARs are closer to one whereas red indicates the median NARs are closer to zero. Overall, among the non-breastfed groups, vitamin B12 and vitamin C NARs are high, towards the green color gradient. Among the breastfed group, NAR(s) for vitamin A and vitamin C are high. Across both age groups, median NARS are closer to zero for zinc, folate, iron and calcium. There is seasonality in NAR(s) folate, vitamin A, iron, and calcium.

Energy intake (Model 1)

The presence of weak La Niña was associated with a greater energy intake of 85-94 kcal/day, and this finding is consistent with the both random and fixed effects model results (Table 5-4). After adjusting for weight, there were gender differences in overall energy intake; girls consumed 88-93 kcal/day less (among the 9-15-months age group) compared to boys, and this difference increases to 112-114 kcal/day by 25-30 months. In addition, on average, girls consumed 155-172 kcal/day less compared to boys during moderate La Niña. Energy intakes varied by seasons - from March to October, there were higher intakes of 63-78 kcal/day. Energy intake was also positively associated with owning assets but not with income or sanitation score. Breastfed children had lower energy intake of 241-265 kcal/day from dietary sources as expected because energy from the breast milk were not quantified in this study.

Macronutrient intakes (Model 2)

The presence of weak La Niña conditions were associated with increased intakes of carbohydrates by 4 grams, and reduced protein by 1 gram and animal source protein by 1 gram (see Table 5-5 for ENSO variables and supplement Table 5-10 for full list of covariates). There was a marginal increase in intake of meat/fish/poultry protein during weak El Niño. The differences in intake by gender under weak La Niña were also apparent in the intakes of overall protein and animal source protein intake with girls consuming 1 gram more than boys, for both dietary variables.

In these models, breastfeeding status, birth order, maternal education and energy intake affected the intakes of macronutrients and iron from flesh foods. There were only marginal influences of seasons and assets on intake. Compared to first-born, there is reduced intake of protein, in particular, animal source protein and flesh meat protein.

Interestingly, there was an inverse relationship between maternal education and intake of flesh protein and iron from flesh foods. There were marginally higher intakes of flesh meat protein in July, and reduced intakes of iron from flesh foods in November and December. Birth month-year and illness were not associated with macronutrient intake.

Micronutrient intakes (Model 3)

Shown in table 5-6 are the model results of ENSO exposures on nutrient intakes. Of the seven micronutrient examined, vitamin C, calcium, iron, and zinc intakes show significant overall differences by ENSO severity (Table 5-6), in addition, calcium, iron, and zinc show differences by ENSO severity among girls. Vitamin A intakes were not associated with ENSO severity, however, vitamin A intake did differ by gender at different age groups (see Table 5-11 in the Supplement material for the full list of covariates). Under weak La Niña, there were negative associations for calcium (82 mg), iron (1 mg), and zinc (0.3 mg). Under strong La Niña, there were also negative associations for calcium (95 mg), and iron (2.0 mg). Under moderate ENSO conditions, both phases show increases in vitamin C intake (21-36 mg), but reduced intake of iron (2.0 mg). After adjusting for energy, breast milk in the diet did not affect micronutrient intakes from non-breast milk foods. Energy and seasonality were strongly associated with nutrient intakes. SES factors such as assets and maternal education were not associated with intakes, but there was a marginal association between income and folate intake.

Micronutrient Adequacy Ratios (Model 4 & 5)

Shown in Table 5-7 are the random effects model results of ENSO exposure on the seven NAR. Of the seven NAR (not truncated at 1.0), vitamin A, vitamin C, calcium, iron, zinc, and folate showed varied intake under different ENSO conditions, especially during

La Niña phases. Although most NARs were reduced under La Niña, folate adequacy increased under severe La Niña (24%). Under weak La Niña, NAR reduced by 0.19 for calcium, 0.08 for iron, and 0.04 for zinc. This was further reduced under severe La Niña. There were no statistically significant reductions of NARs in any of the El Niño conditions, except for a marginal decrease in Vitamin A NAR by 0.19 under weak El Niño.

There were gender differences in vitamin B12 NAR, girls had 0.30 lower NAR than boys ($P<0.075$). Under moderate El Niño, marginal reductions in NAR was observed among the girls for iron and zinc. Under weak La Niña, girls had a slightly higher NAR compare to boys. There was a strong negative trend in all of the NAR with increasing age, except for vitamin C (see table 5-12 in the supplement material for full list of covariates). Birth order showed no associations with the NAR. Further, there were very small associations between SES status and illness with NAR. Birth month and year were significantly associated with decreased NARs of calcium and iron, whereas increased NAR for folate. There were seasonal reductions in vitamin A NAR from April to July and vitamin B12 NAR from February to April, whereas the NAR for calcium and iron increased from February to April. Higher NAR for vitamin C was found in December. Having breast milk in the diet was significantly and positively associated with NAR for vitamin A, vitamin C, calcium (marginal significance of $p<0.10$), folate and vitamin B12.

When the above results were compared to NARs bounded at 1.0, consistent trend were observed but a smaller magnitude (see Table 5-8 for models results for ENSO variables and 5-13 for complete list of covariates). For example, folate NAR increased by 0.15 in strong La Niña, while in the previous model, it increased by 0.24. Under El Niño conditions, vitamin C showed higher adequacy (4%). Interestingly, SES showed greater association with NARs bounded at 1.0 then compared to the previous model. Maternal education was positively associated with vitamin A and calcium NAR. Income was not associated with any of the NARs while the previous model showed small and marginally significant association between income and folate.

Discussion

The relationships between season of the year and nutrient intakes among children have been well documented since the 1970s, as crop productivity is ultimately tied to differences in environmental factors such as temperature and precipitation (Schofield 1974; Brown et al. 1982a; Marín et al. 1996; Graham 2003). This is the first study to show the impact of ENSO conditions on the nutrient intakes of young children. Under moderate La Niña phase, there were reduced intake of energy, and this reduction was greater among girls than boys. We also found reduced intakes of protein, animal source protein, but increased energy intake during weak La Niña. This is likely because weak La Niña follow severe El Niño conditions, and could be viewed as a reprieve from dry conditions to more wet conditions (with higher river discharge) that are usually observed under La Niña phases. Under these conditions, crop productivity is likely higher than in previous drought like conditions.

In the previous report examining ENSO exposure and food consumption patterns, we saw there were marginal increases in foods containing plantains, poultry, and/or meat during weak La Niña conditions. These increases in meal patterns with poultry and meat were only consistent among girls who had increased intakes of protein and animal source protein. A possible explanation for this observation is that animal source protein intakes includes fish, beef, pork, chicken, wild meat armadillo, turtle, wild hogs, other wild animals, and dairy, whereas models with meal frequency only considered consumption of meat (does not include dairy) or consumption of poultry or consumption dairy separately. We do see that increased intake of meals with poultry (pvalue <0.10) corresponding to increased intake of meat fish poultry protein by 1 gram under weak El Niño conditions. Energy intake was significantly higher under weak La Niña conditions, which could be related to the increased consumption of meals with poultry, plantains and meat during the same period. The significant reduction in energy intake under moderate El Niño could be attributed to the reduced consumption of meals containing plantains and fish during the same period. Similarly, for girls the significant reduction in energy intake under moderate El Niño could be attributed to meals containing plantains, which were reduced by 70%.

When we examined the NAR, calcium and iron showed the largest reductions during La Niña conditions compared to folate, vitamin C, and vitamin B12. Despite overall reduction in NARs under La Niña conditions, girls generally had higher NAR for calcium, iron and zinc, which could be attributed to the increased intake of animal source protein, and meat/fish/poultry protein. We did not observe any overalls reduction of NAR under any of the El Niño conditions, except for marginal reduction in NAR for vitamin A. There were reductions observed among girls for iron and zinc NAR under moderate El Niño conditions but these were only marginally significant. When compared to the NAR bounded at 1.0 model, the results were consistent except for calcium. These results were also consistent in the fixed effects models (results not shown).

There are several possible explanations as to why we saw smaller effect sizes in NAR under various ENSO exposures. First, there were low prevalences of nutrient adequacies. Only vitamin C was sufficient but only among the breastfed group. Because the intakes were low to begin with, any reduction in intake that could result from ENSO exposure are also small, and thus hard to detect. Second, exposure to severe ENSO phases was limited in the younger age groups, where breast milk was still significant source of nutrients.

Socioeconomic status was associated with the energy intake, iron, and protein from flesh meat, especially assets and maternal education. Surprisingly, we did not see SES components significantly associated with the NAR, given that past literature has found maternal education, income and other economic factors to be related to dietary adequacy of children in other settings (Chaudhury 1984; Watt et al. 2001).

However, there were significant differences in NAR by breastfeeding status, particularly for the 16-24 months age group. This is likely because children are transitioning completely to family foods during this time as they are weaned from breast milk. Seasonal difference in energy, flesh meat, iron from flesh meat are not surprising. In Loreto, crop productivity of rice, vegetables and fruits are seasonal, whereas, the availability of other commonly substituted staples such as plantains and yucca are not. In the previous report, availability of fish during summer (June to November) resulted in larger amounts of fish consumed, which could explain the higher intakes of flesh meat and iron from flesh mea/iron in the summer. This could be related to increased livelihood activities during the summer months (June to November) because when the river level is lower, there is greater access to forest products, fishing, and income, thus greater access to a variety of foods.

There are several strengths and limitations to this study. This study had a prospective design with up to 27 visits per child with various exposures to ENSO phases over a period of four years, which enabled us to account for temporality in exposures.

Second, nutrient information was rigorously checked for quality. Finally, we compared several models to check the robustness of the findings. The limitations of the study are that moderate El Niño and La Niña occurred over a short period and we had fewer dietary recalls during this period (n=169, n=74 respectively). Second, breast milk nutrient intakes were not quantified. Breast milk nutrient content (used to estimate the nutrient need from non-breast milk foods) comes from the Institute of Medicine report from 1991 (World Health Organization 1998) – 25 years before the collection of data reported in this analysis. In particular, vitamin B12 estimates were from an analysis of breast milk from a 1981 study of 21 mothers from Le Leche League International (Sandberg et al. 1981). These nutrient estimates may not reflect breast milk nutrient profiles in Peru. For example, vitamin B12 concentrations of breast milk among 183 low-income women in Guatemala were below the limits of detection using a new tool (Allen 2012). Thus, there exists a serious need to consolidate current literature on human milk composition with standardized methods, and to develop field friendly ways to quantify nutrients from breast milk (Allen 2012).

The gender differences observed in energy intake, nutrient intakes, and adequacies are perplexing because studies done in other parts of Peru have found nutritional buffering by mothers without gender differences (Leonard 1991; Graham 1997; Messer 1997). These studies have sample sizes of 22-26 to compare gender differences in energy intakes. It is possible these studies were underpowered to detect the difference in energy intake. Further, there was no information available on breastfeeding prevalence or how would this differ by gender. More importantly, these studies were conducted in different socio-ecological zones of Peru, which may not be generalizable to the Amazonian context. In a more recent study conducted in the Brazilian Amazon, Piperata and colleagues found there was general nutritional buffering of children by mothers, but boys did have a slight advantage with respect to protein intakes compared to girls (Piperata et al. 2013). They also found that boys had higher energy intakes, but the effect was not statistically significant (sample size = 51). In another longitudinal study conducted in Guatemala, Frongillo and colleagues illustrated the existence of gender bias, where boys on average consumed 49-67 Kcal more than girls from 12-36 months of age after controlling for child, maternal, and household factors (Frongillo and Bégin 1993). The study had 938 observations among the 12-24 months age group and 637 observations among the 24-36-months age group.

Biases in intra-household food allocation have important consequences, mainly, that it results in poor nutritional, cognitive and mortality outcomes in the adversely affected gender (Frongillo and Bégin 1993; Messer 1997). The recent study examining stature before and after the 1998 severe El Niño event found that lean mass was significantly lower among girls by 5.3Kg (Danysh et al. 2014). It is posited that heads of household or caregivers tend to invest in children with the greatest return for economic output, i.e., males are likely to migrate for jobs and contribute to household income (Messer 1997). In a resource limited setting like the one presented in this analysis, climate and seasonal variations affect food procuring strategies and appear to negatively affect girls. Gender is a fundamental lens in dealing with effects of climate changes, for example, women, and girls are more likely to have higher mortality during natural disasters (Skinner et al. 2011). It is critical to understand and evaluate if gender inequalities manifest in other dimensions (social, health care, education) or occur more frequently under severe and prolonged ENSO exposures.

Tables & Figures

Table 5-1: Modelling framework for nutrient intakes among Children 9-36 months

Model	Main outcome	Main Exposure	Covariates	Effect Modifiers	Modelling Framework
1	Energy	ENSO severity	SES factors, birth order, season, birth month-year, Child's weight, breastfeeding, morbidity	Gender & Age	Random Effects (compared with fixed effects) at the child level
2	Carbohydrates, protein, animal source protein, meat/fish/poultry protein, and meat/fish/poultry iron	ENSO severity	SES factors, birth order, season, birth month-year, energy, breastfeeding, morbidity	Gender & Age	Random Effects (compared with fixed effects) at the child level
3	Micronutrient intakes of vitamin A, vitamin C, calcium, zinc, iron, cobalamin, and folate	ENSO severity	SES factors, birth order, season, birth month-year, energy, breastfeeding, morbidity	Gender & Age	Random Effects (compared with fixed effects) at the child level
4	Micronutrient Adequacy Ratio (NAR) of vitamin A, vitamin C, calcium, zinc, iron, cobalamin, and folate	ENSO severity	SES factors, birth order, season, birth month-year, energy, breastfeeding, morbidity	Gender & Age	Random Effects (compared with fixed effects) at the child level
5	NAR bounded at 1.0 of vitamin A, vitamin C, calcium, zinc, iron, cobalamin, and folate	ENSO severity	SES factors, birth order, season, birth month-year, energy, breastfeeding, morbidity	Gender & Age	Random Effects (compared with fixed effects) at the child level

Table 5-2: Household and Child characteristics of MAL-ED Birth Cohort in Iquitos, Peru

Variables	***% or median (IQR)***
Water/Sanitation Score [a]	0 (0, 4)
Assets (out of 8) [a]	5 (4, 6)
Income (USD) [a]	126.6 (104.2, 170.4)
Maternal Education (years) [a]	8 (6,10)
Female %	45.6
Birth order %	
First born	38.9
2^{nd} -4^{th} children	46.8
5^{th} + children	14.3
Weaning Age (months) [a]	18 (15, 22)
Visits per child [a]	27(19, 28)
Child's weight at 9 month (kg) [a]	8.3 (7.6, 9.1)
Child Weight for Age Z score at 9 months [a]	-0.27 (-0.94 -0.35)

[a] These variables have median (IQR)

Table 5-3: Median (IQR) nutrient intake and median Nutrition Adequacy Ratios by age groups and breastfeeding status

Age groups	9-15 months		16-24 months		25-30 months		31-36 months	
	BF	Non-BF	BF	Non-BF	BF	Non-BF	BF	Non-BF
Dietary Recalls (N)	1226	251	763	1131	57	1059	9	956
Energy (kcal)	430.0 (283.4, 627.2)	502.6* (336.9, 760.2)	716.7 (519.2, 914.4)	973.6 * (752.1, 1253.5)	992.3 (754.5, 1265.3)	1134.5 * (887.8, 1475.1)	1214.5 (866.4, 1542.6)	1214.9 (967.6 , 1548.6)
Carbohydrates (g)	50.6 (18.6, 109.1)	62.6 (26.6, 128.0)*	90.4 (46.5, 183.7)	131.9 (69.3, 230.3)*	143.8 (73.4, 229.3)	132.9 (68.6, 233.1)	53.1 (38.4, 209.0)	157.3 (77.7, 246.7)
Protein (g)	11.0 (6.7, 16.9)	12.5 (8.0, 19.1) *	18.1(12.8, 26.2)	24.9 (18.3, 32.9)*	24.4 (19.7, 33.9)	26.9 (20.2, 35.0)	26.1 (15.6, 36.4)	28.8 (22.3, 37.7)
Animal Source Protein (g)	6.0 (3.0, 10.5)	7.3 (3.6, 12.6)*	11.2 (6.5, 17.3)	16.3 (10.3, 22.9)*	14.7 (11.0, 21.8)	16.0 (11.1, 23.3)	15.9 (9.8, 17.5)	17.8 (12.2, 25.1)
Meat, Fish, Poultry Iron (mg)	0.2 (0.0, 0.6)	0.2 (0.0, 0.5)	0.4 (0.2, 0.9)	0.5 (0.2, 1.1)*	0.4 (0.2, 0.9)	0.6 (0.3, 1.2)*	0.4 (0.4, 1.8)	0.7 (0.3, 1.5)
Vitamin A (µg~RE)	83.4 (35.3, 178.4)	113.2 (47.4, 236.7)	121.9 (58.1, 231.9)	206.8 * (107.4, 368.3)	208.9 (115.3, 389.1)	220.7 (117.3, 414.8)	324.3 (91.8 , 512.3)	231.2 (120.9, 398.5)
Vitamin C (mg)	12.7 (5.1, 38.0)	14.1 (5.8, 50.2)	21.7 (10.3, 73.7)	31.8 (14.2, 102.5)*	23.3 (13.9, 50.5)	31.8 (15.9, 92.5)	19.9 (12.6, 32.0)	32.7 (17.3, 91.9)
Calcium (mg)	76.8 (34.5, 182.3)	100.5 * (42.2, 240.3)	117.1 (59.0, 227.2)	222.2 * (103.6, 418.7)	121.2 (56.1, 286.6)	222.2 (103.6, 418.7)	139.6 (127.7, 181.5)	225.9 (108.8, 393.3)
Iron (mg)	1.9 (1.2, 3.2)	2.2 (1.4, 3.4)+	3.1 (2.1, 4.5)	4.0 (2.8, 6.0)*	4.5 (3.0, 6.0)	4.4 (3.2, 6.1)	5.3 (3.0, 6.0)	4.7 (3.4, 6.3)
Folate (µg)	31.8 (18.3, 52.3)	37.6 (20.8, 58.1)*	47.4 (30.1, 74.3)	61.2 (41.9, 89.8)*	67.9 (45.9, 92.0)	67.8 (46.3, 99.6)	77.8(38.2, 104.6)	71.8 (48.6, 102.0)
Zinc (mg)	1.2 (0.7, 1.9)	1.4 (0.9, 2.2)*	2.0 (1.3, 2.9)	2.8 (2.0, 4.1)*	2.6 (2.0, 3.8)	3.0 (2.2, 4.2)+	2.5 (1.7, 3.8)	3.2 (2.3, 4.3)

Vitamin B-12	0.4 (0.1, 0.8)	0.4 (0.1, 1.0)	0.6 (0.3, 1.3)	0.4 (0.1, 1.0)*	0.9 (0.6, 1.9)	0.9 (0.4, 1.6)	0.5 (0.1, 1.6)	1.0 (0.5, 1.7)
<u>Nutrient Adequacy Ratios :</u>								
Vitamin A (µg~RE)	0.8 (0.3, 1.6)	0.3 (0.1, 0.6)*	1.0 (0.5, 1.8)	0.5 (0.3, 0.9)*	1.7 (0.9, 3.1)	0.6 (0.3, 1.0)*	2.6 (0.7, 4.1)	0.6 (0.3, 1.0)*
Vitamin C (mg)	1.8 (0.8, 5.7)	0.5 (0.2, 1.7)*	2.7 (1.3, 9.2)	1.1 (0.5, 3.4)*	2.9 (1.7, 6.3)	1.1 (0.5, 3.1)*	2.5 (1.6, 4.0)	1.1 (0.6, 3.1)
Calcium (mg)	0.3 (0.1, 0.6)	0.2 (0.1, 0.5)	0.3 (0.2, 0.7)	0.4 (0.2, 0.8)*	0.4 (0.2, 0.8)	0.4 (0.2, 0.8)	0.4 (0.4, 0.5)	0.5 (0.2, 0.8)
Iron (mg)	0.1 (0.1,0.2	0.2 (0.1, 0.3)*	0.3 (0.2, 0.4)	0.3 (0.2, 0.5)*	0.4 (0.3, 0.5)	0.4 (0.3, 0.5)	0.4 (0.2, 0.5)	0.4 (0.3, 0.5)
Folate (µg)	0.5 (0.3, 1.0)	0.3 (0.2, 0.5)*	0.4 (0.3, 0.7)	0.4 (0.3, 0.6)*	0.6 (0.4, 0.8)	0.4 (0.3, 0.6)*	0.7 (0.3, 0.9)	0.4 (0.3, 0.6)
Zinc (mg)	0.2 (0.1, 0.3)	0.2 (0.1, 0.3)+	0.3(0.2, 0.4)	0.3(0.2, 0.5)*	0.3 (0.3, 0.5)	0.4 (0.3, 0.5)	0.3 (0.2, 0.5)	0.4 (0.3, 0.5)
Vitamin B-12	0.5 (0.2, 1.3)	0.6 (0.2, 1.3)	0.5 (0.2, 1.3)	1.0 (0.5, 1.7)*	0.9 (0.6, 1.9)	1.0 (0.5, 1.8)	0.5 (0.1, 1.6)	1.1 (0.5, 1.9)

BF: breastfeeding; Non-BF: weaned; T-test results between BF and non BF are indicated by * for significant at $p < 0.05$ level and + for significant at $p < 0.07$.

Figure 5-1: Heat map of median Nutrient Adequacy Ratios by breastfeeding status and season

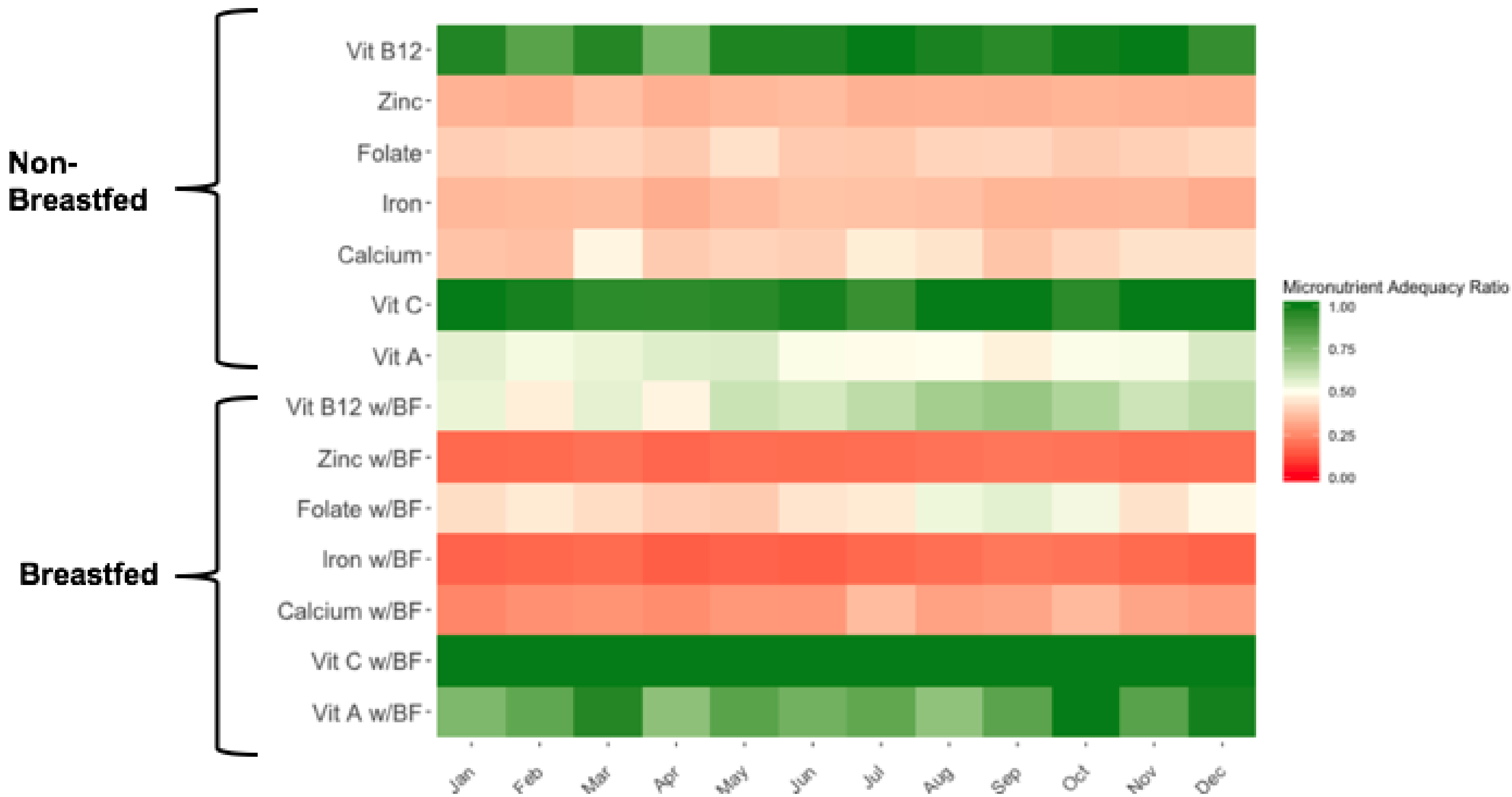

Table 5-4: Model results from random and fixed effects regression on ENSO exposure on energy intake

	Random Effects	*Fixed Effects*
	Energy (kcal)	
Neutral condition	Reference	Reference
weak El Niño	6.903 [-45.511,59.317]	5.080 [-47.268,57.427]
moderate El Niño	-80.766* [-150.257,-11.276]	-80.124* [-150.437,-9.811]
weak La Niña	85.517* [35.032,136.003]	94.649* [42.928,146.370]
moderate La Niña	-2.080 [-90.939,86.778]	12.686 [-77.890,103.263]
strong La Niña	13.200 [-66.235,92.636]	36.377 [-49.951,122.706]
Male	Reference	-
Female	25.058 [-28.401,78.517]	-
weak El Niño # Female	20.149 [-48.222,88.520]	20.428 [-47.928,88.785]
moderate El Niño # Female	40.665 [-46.251,127.580]	39.852 [-47.617,127.321]
weak La Niña # Female	-16.490 [-79.802,46.822]	-21.078 [-85.739,43.584]
moderate La Niña # Female	-155.665* [-262.621,-48.709]	-172.093* [-282.285,-61.901]
strong La Niña # Female	-72.124 [-194.709,50.462]	-87.558 [-216.315,41.199]
9-15m	Reference	Reference
16-24m	226.469* [180.989,271.950]	200.022* [151.286,248.758]
25-30m	362.055* [286.861,437.250]	309.108* [228.441,389.775]
31-36m	350.489* [257.830,443.147]	280.195* [178.365,382.024]
Female # 16-24m	-89.375* [-149.784,-28.965]	-92.633* [-154.189,-31.077]
Female # 25-30m	-112.433* [-197.472,-27.393]	-114.665* [-201.279,-28.051]
Female # 31-36m	-76.604 [-171.870,18.662]	-79.717 [-176.237,16.804]
1st child	Reference	-
2-4 children	1.306 [-55.821,58.433]	-
5 + children	62.743+ [-11.766,137.251]	-

Jan	Reference	Reference
Feb	-3.879 [-24.943,17.184]	-2.905 [-24.000,18.191]
Mar	37.067* [8.719,65.414]	38.606* [10.170,67.043]
Apr	39.517* [4.578,74.457]	40.702* [5.646,75.759]
May	16.501 [-23.947,56.950]	20.508 [-20.509,61.524]
Jun	45.926* [4.811,87.041]	48.929* [7.258,90.600]
Jul	78.692* [34.139,123.245]	80.328* [35.139,125.518]
Aug	23.916 [-19.840,67.672]	24.505 [-19.684,68.694]
Sep	40.090* [3.732,76.449]	42.279* [5.531,79.028]
Oct	57.040* [22.953,91.127]	59.613* [25.178,94.048]
Nov	46.399* [14.335,78.462]	49.289* [17.176,81.403]
Dec	23.171* [1.010,45.333]	27.325* [5.068,49.581]
Illness	0.663 [-0.600,1.927]	1.102+ [-0.173,2.377]
Asset	16.161+ [-1.372,33.694]	
Sanitation Score	-11.222 [-26.456,4.012]	-
Income	0.277 [-0.097,0.651]	-
Weight (kg)	74.645* [52.904,96.386]	90.724* [64.146,117.303]
No Breastfeeding	Reference	Reference
Breastfeeding	-234.966* [-274.737,-195.195]	-246.654* [-291.380,-201.929]
Constant	-155.551 [-395.003,83.902]	-149.742 [-412.293,112.810]
Observations	5423	5423
AIC	-	76,109.055

95% confidence intervals in brackets
+ $p < 0.10$, * $p < 0.05$

Table 5-5: Random effects model results of ENSO exposure on macronutrient intake and iron from meat/fish/poultry sources (see table 5-10 for full list of covariates)

	Carbohydrate (g)	Protein (g)	Animal Source Protein (g)	Meat Fish Poultry Protein (g)	Meat Fish Poultry Iron (mg)
Neutral			Reference		
weak El Niño	-1.09	0.58	0.7	0.91*	0.06
	[-4.46,2.28]	[-0.44,1.61]	[-0.33,1.73]	[0.04,1.78]	[-0.09,0.21]
moderate El Niño	-2.15	0.81	0.06	0.57	0.14
	[-7.34,3.03]	[-0.83,2.45]	[-1.75,1.86]	[-1.13,2.27]	[-0.32,0.60]
weak La Niña	3.79*	-1.26*	-1.02*	0.25	0.08
	[0.84,6.74]	[-2.12,-0.41]	[-1.89,-0.14]	[-0.57,1.07]	[-0.05,0.22]
moderate La Niña	-2.38	-0.17	0.76	-0.31	-0.14
	[-8.05,3.29]	[-1.50,1.15]	[-0.76,2.28]	[-1.73,1.12]	[-0.39,0.12]
strong La Niña	0.12	-0.4	0.26	0.55	0
	[-3.88,4.12]	[-1.57,0.78]	[-0.99,1.51]	[-0.63,1.73]	[-0.15,0.16]
Male			Reference		
Female	0.12	-0.27	-0.44	-0.13	-0.05
	[-2.67,2.91]	[-1.06,0.51]	[-1.32,0.45]	[-0.85,0.59]	[-0.16,0.05]
weak El Niño # Female	3.14	-0.59	-0.1	0.1	-0.04
	[-1.21,7.49]	[-1.97,0.79]	[-1.51,1.31]	[-1.14,1.34]	[-0.23,0.15]
moderate El Niño # Female	4.31	-1.89+	-0.68	-0.43	-0.14
	[-2.58,11.19]	[-3.98,0.21]	[-2.99,1.64]	[-2.62,1.77]	[-0.63,0.34]
weak La Niña # Female	-1.95	0.97+	1.34*	-0.13	-0.07
	[-5.46,1.56]	[-0.04,1.97]	[0.22,2.45]	[-1.18,0.92]	[-0.23,0.09]
moderate La Niña Female	5.21	-0.37	-1.1	-0.7	-0.01
	[-2.38,12.80]	[-2.34,1.60]	[-3.28,1.07]	[-2.56,1.16]	[-0.27,0.26]
strong La Niña # Female	-0.95	0.5	0.32	-0.82	-0.1
	[-7.64,5.74]	[-1.09,2.09]	[-1.46,2.10]	[-2.30,0.67]	[-0.28,0.09]
Observations	5443	5443	5443	5443	5443

95% confidence intervals in brackets

Table 5-6: Random effects model results of ENSO exposure on nutrient Intakes of children 9-36 months of age (see supplemental table full list of covariates)

	Vitamin A (µg~RE)	*Vitamin C (mg)*	*Folate (µg)*	*Vitamin B-12 (µg)*	*Calcium (mg)*	*Iron (mg)*	*Zinc (mg)*
Neutral				Reference			
Weak El Niño	-15.26	3.71	-1.07	0.06	30.56	0.34	-0.01
	[-62.45,31.94]	[-16.82,24.24]	[-6.46,4.31]	[-0.15,0.28]	[-20.73,81.85]	[-0.66,1.34]	[-0.20,0.17]
Moderate El Niño	27.79	20.63*	4.04	0.28	66.89^{+}	1.29^{+}	0.07
	[-113.49,169.07]	[2.51,38.75]	[-7.59,15.68]	[-0.42,0.99]	[-11.10,144.89]	[-0.06,2.64]	[-0.17,0.32]
Weak La Niña	-3.36	8.82	0.68	-0.01	-82.77*	-1.07*	-0.31*
	[-45.72,38.99]	[-24.18,41.81]	[-5.85,7.20]	[-0.18,0.17]	[-128.08,-37.45]	[-1.81,-0.33]	[-0.50,-0.12]
Moderate La Niña	-33.4	38.46*	-8.26	-0.11	-55.8	-2.10*	-0.13
	[-106.41,39.61]	[16.77,60.15]	[-18.43,1.92]	[-0.43,0.20]	[-155.56,43.96]	[-3.35,-0.84]	[-0.31,0.06]
Strong La Niña	-25.15	-19.5	-2.68	-0.05	-95.54*	-1.97*	-0.14
	[-92.28,41.98]	[-44.41,5.41]	[-11.14,5.79]	[-0.31,0.21]	[-168.27,-22.81]	[-3.08,-0.85]	[-0.34,0.06]
Male				Reference			
Female	-20.62	-1.6	-4.47	-0.15	-7.84	-0.15	-0.01
	[-75.56,34.32]	[-22.85,19.66]	[-10.18,1.24]	[-0.34,0.05]	[-58.46,42.79]	[-1.06,0.77]	[-0.20,0.18]
weak El Niño # Female	-20.98	-14.84	-4.43	-0.2	-27.21	-0.41	-0.14
	[-78.16,36.21]	[-51.66,21.97]	[-11.24,2.39]	[-0.44,0.04]	[-96.36,41.94]	[-1.76,0.94]	[-0.38,0.09]
moderate El Niño # Female	-13.19	-16.12	-10.19	-0.49	-82.31	-1.57^{+}	-0.32^{+}
	[-161.20,134.83]	[-41.85,9.62]	[-22.87,2.48]	[-1.19,0.21]	[-182.13,17.52]	[-3.29,0.14]	[-0.66,0.01]
weak La Niña # Female	-23.45	11.5	2.41	0.07	49.31	0.11	0.32*
	[-80.06,33.17]	[-38.86,61.85]	[-5.71,10.54]	[-0.16,0.29]	[-11.77,110.38]	[-0.88,1.11]	[0.09,0.55]
moderate La Niña # Female	0.61	-1.63	4.46	0.02	57.41	1.28	0.15
	[-85.21,86.42]	[-24.13,20.88]	[-7.10,16.02]	[-0.31,0.34]	[-62.93,177.75]	[-0.55,3.11]	[-0.12,0.41]
strong La Niña # Female	-25	-1.64	0.3	0.01	94.52*	1.18	0.2
	[-100.84,50.83]	[-33.73,30.44]	[-10.59,11.20]	[-0.28,0.30]	[7.18,181.86]	[-0.24,2.59]	[-0.08,0.49]

Observations	5443	5443	5443	5443	5443	5443	5443

Table 5-7: Random effects model results on NAR (not truncated at 1.0)

NAR	*Random Effects*						
	Vitamin A	Vitamin C	Calcium	Iron	Folate	Zinc	Vitamin B12
Neutral				Reference			
weak El Niño	-0.19+	0.99	0.05	0.03	0.01	0	0.11
	[-0.40,0.02]	[-0.32,2.29]	[-0.07,0.16]	[-0.05,0.11]	[-0.05,0.06]	[-0.02,0.02]	[-0.15,0.37]
moderate El Niño	-0.22	0.34	0.11	0.10+	0.06	0.01	0.44
	[-0.65,0.20]	[-1.25,1.93]	[-0.08,0.29]	[-0.01,0.21]	[-0.08,0.20]	[-0.02,0.04]	[-0.39,1.26]
weak La Niña	0.02	1.75	-0.19*	-0.08*	0.05	-0.04*	-0.03
	[-0.23,0.28]	[-1.28,4.79]	[-0.30,-0.09]	[-0.14,-0.02]	[-0.03,0.13]	[-0.06,-0.01]	[-0.25,0.20]
moderate La Niña	-0.62*	0.09	-0.15	-0.19*	-0.12	-0.02	-0.18
	[-1.07,-0.16]	[-2.11,2.30]	[-0.45,0.14]	[-0.27,-0.10]	[-0.28,0.04]	[-0.04,0.00]	[-0.61,0.25]
strong La Niña	-0.26	-2.17+	-0.24*	-0.18*	0.24*	-0.02	0.07
	[-0.76,0.24]	[-4.53,0.19]	[-0.43,-0.05]	[-0.27,-0.09]	[0.07,0.41]	[-0.04,0.01]	[-0.36,0.51]
Male				Reference			
Female	-0.23	0.08	-0.04	-0.01	-0.06	0	-0.30+
	[-0.70,0.24]	[-2.29,2.45]	[-0.21,0.12]	[-0.08,0.06]	[-0.19,0.08]	[-0.02,0.02]	[-0.64,0.04]
weak El Niño # Female	0.11	-0.32	-0.05	-0.03	-0.04	-0.02	-0.24
	[-0.13,0.36]	[-2.26,1.62]	[-0.19,0.10]	[-0.15,0.08]	[-0.11,0.03]	[-0.04,0.01]	[-0.53,0.06]
moderate El Niño # Female	0.36	-0.28	-0.15	-0.12+	-0.08	-0.04+	-0.63
	[-0.20,0.92]	[-2.05,1.49]	[-0.37,0.07]	[-0.26,0.02]	[-0.23,0.08]	[-0.08,0.00]	[-1.45,0.19]
weak La Niña # Female	-0.05	1.11	0.15*	0	0.02	0.04*	0.17
	[-0.43,0.33]	[-3.01,5.23]	[0.00,0.29]	[-0.08,0.08]	[-0.11,0.15]	[0.01,0.07]	[-0.13,0.47]
moderate La Niña # Female	-0.01	-0.47	0.21	0.10+	0.13	0.01	0.09
	[-0.63,0.61]	[-3.90,2.96]	[-0.22,0.64]	[-0.01,0.20]	[-0.14,0.40]	[-0.02,0.05]	[-0.40,0.58]

strong La Niña # Female	-0.37	0.37	0.22⁺	0.11⁺	-0.1	0.02	0.12
	[-0.99,0.25]	[-3.44,4.18]	[-0.04,0.48]	[-0.00,0.23]	[-0.42,0.22]	[-0.01,0.06]	[-0.46,0.71]
Observations	5443	5443	5443	5443	5443	5443	5443

Table 5-8: Random effects model results of ENSO exposure on NAR bounded at 1.0 among children 9-36 months of age

NAR bounded at 1.0	*Random Effects Model*						
	Vitamin A	Vitamin C	Calcium	Iron	Folate	Zinc	Vitamin B12
Neutral				Reference			
weak El Niño	-0.003	0.038*	-0.017	-0.005	0.007	-0.003	0.01
	[-0.042,0.035]	[0.007,0.068]	[-0.056,0.021]	[-0.033,0.023]	[-0.022,0.036]	[-0.021,0.014]	[-0.024,0.043]
moderate El Niño	-0.03	0.02	0.029	0.02	0.045	0.01	0.005
	[-0.105,0.045]	[-0.033,0.072]	[-0.040,0.098]	[-0.025,0.066]	[-0.014,0.103]	[-0.019,0.039]	[-0.066,0.077]
weak La Niña	-0.012	0.027⁺	-0.042⁺	-0.034*	0.038*	-0.026*	0.033⁺
	[-0.048,0.024]	[-0.001,0.056]	[-0.084,0.001]	[-0.063,-0.004]	[0.004,0.073]	[-0.044,-0.008]	[-0.004,0.071]
moderate La Niña	-0.025	0	-0.116*	-0.089*	-0.004	-0.014	-0.054
	[-0.125,0.074]	[-0.083,0.083]	[-0.198,-0.034]	[-0.144,-0.033]	[-0.110,0.101]	[-0.037,0.008]	[-0.165,0.058]
strong La Niña	-0.01	0.016	-0.099*	-0.108*	0.150*	-0.023*	0.076
	[-0.086,0.066]	[-0.051,0.083]	[-0.182,-0.016]	[-0.156,-0.060]	[0.079,0.221]	[-0.046,-0.001]	[-0.037,0.188]
Male				Reference			
Female	-0.006	0.007	0.004	-0.022	-0.023	-0.003	-0.029
	[-0.057,0.044]	[-0.034,0.047]	[-0.053,0.062]	[-0.062,0.019]	[-0.066,0.021]	[-0.023,0.016]	[-0.090,0.032]
weak El Niño # Female	-0.037	-0.056*	0.02	-0.003	-0.039⁺	-0.012	-0.019
	[-0.089,0.014]	[-0.100,-0.013]	[-0.030,0.070]	[-0.038,0.033]	[-0.078,0.001]	[-0.035,0.010]	[-0.063,0.025]
moderate El Niño # Female	-0.003	-0.058⁺	-0.049	-0.033	-0.055	-0.041*	-0.065
	[-0.092,0.086]	[-0.126,0.011]	[-0.137,0.039]	[-0.094,0.029]	[-0.128,0.018]	[-0.078,-0.004]	[-0.159,0.029]
weak La Niña # Female	-0.008	-0.004	0.065*	0.033⁺	-0.001	0.034*	0.006

	[-0.060,0.045]	[-0.047,0.039]	[0.004,0.126]	[-0.005,0.071]	[-0.051,0.049]	[0.009,0.059]	[-0.049,0.060]
moderate La Niña # Female	-0.038	0.009	0.104	0.055	0.068	0.007	-0.044
	[-0.189,0.114]	[-0.100,0.118]	[-0.037,0.245]	[-0.027,0.137]	[-0.085,0.222]	[-0.024,0.037]	[-0.220,0.132]
strong La Niña # Female	-0.006	-0.037	0.092	0.074^{+}	-0.037	0.025	0.007
	[-0.112,0.101]	[-0.125,0.052]	[-0.041,0.226]	[-0.014,0.161]	[-0.167,0.093]	[-0.009,0.058]	[-0.154,0.168]
Observations	5443	5443	5443	5443	5443	5443	5443

Supplemental Material:

Table 5-9: Recommended Nutrient Intake by breastfeeding status

	UN RNI			Nutrients from Breast milk		Gap filled by complementary feeding	
Micronutrients/minerals	9-11 months	1-3 years	Estimate BM intake per L	9-11 months (616g/day)	12-36 months (549g/day)	9-11 months	12-36months
Calcium (mg/day)	400	500	280	172	154	228	346
Zinc (mg/day at low bioavailability)	8.3	8.4	1.2	0.7	0.7	7.6	7.7
Iron (mg/day at 5% bioavailability)	18	12	0.3	0	0	18	12
Vitamin A (ug_RE/day)	400	400	500	308	275	92	126
Vitamin C (mg/day)	30	30	40	25	22	5	8
Folate - B9 (ug/day)	80	160	85	52.4	46.7	27.6	113.3
Cobalamin (ug/day) B12	0.5	0.9	0.97	0.60	0.53	-0.10	0.37

Table 5-10: Random effects model results of ENSO exposure on macronutrient intake and iron from meat/fish/poultry sources

	Carbohydrate (g)	Protein (g)	Animal Source Protein (g)	Meat Fish Poultry Protein (g)	Meat Fish Poultry Iron
Neutral			Reference		
weak El Niño	-1.09	0.58	0.7	0.91*	0.06
	[-4.46,2.28]	[-0.44,1.61]	[-0.33,1.73]	[0.04,1.78]	[-0.09,0.21]
moderate El Niño	-2.15	0.81	0.06	0.57	0.14
	[-7.34,3.03]	[-0.83,2.45]	[-1.75,1.86]	[-1.13,2.27]	[-0.32,0.60]
weak La Niña	3.79*	-1.26*	-1.02*	0.25	0.08
	[0.84,6.74]	[-2.12,-0.41]	[-1.89,-0.14]	[-0.57,1.07]	[-0.05,0.22]
moderate La Niña	-2.38	-0.17	0.76	-0.31	-0.14
	[-8.05,3.29]	[-1.50,1.15]	[-0.76,2.28]	[-1.73,1.12]	[-0.39,0.12]
strong La Niña	0.12	-0.4	0.26	0.55	0
	[-3.88,4.12]	[-1.57,0.78]	[-0.99,1.51]	[-0.63,1.73]	[-0.15,0.16]
Male			Reference		
Female	0.12	-0.27	-0.44	-0.13	-0.05
	[-2.67,2.91]	[-1.06,0.51]	[-1.32,0.45]	[-0.85,0.59]	[-0.16,0.05]
weak El Niño # Female	3.14	-0.59	-0.1	0.1	-0.04
	[-1.21,7.49]	[-1.97,0.79]	[-1.51,1.31]	[-1.14,1.34]	[-0.23,0.15]
moderate El Niño # Female	4.31	-1.89+	-0.68	-0.43	-0.14
	[-2.58,11.19]	[-3.98,0.21]	[-2.99,1.64]	[-2.62,1.77]	[-0.63,0.34]
weak La Niña # Female	-1.95	0.97+	1.34*	-0.13	-0.07
	[-5.46,1.56]	[-0.04,1.97]	[0.22,2.45]	[-1.18,0.92]	[-0.23,0.09]
moderate La Niña # Female	5.21	-0.37	-1.1	-0.7	-0.01
	[-2.38,12.80]	[-2.34,1.60]	[-3.28,1.07]	[-2.56,1.16]	[-0.27,0.26]
strong La Niña # Female	-0.95	0.5	0.32	-0.82	-0.1
	[-7.64,5.74]	[-1.09,2.09]	[-1.46,2.10]	[-2.30,0.67]	[-0.28,0.09]
9-15m			Reference		

16-24m	-3.81*	1.94*	1.63*	2.19*	0.17*
	[-7.14,-0.48]	[1.18,2.70]	[0.74,2.52]	[1.52,2.87]	[0.07,0.28]
25-30m	3.25	-0.03	-0.58	2.74*	0.14
	[-1.63,8.13]	[-1.22,1.17]	[-1.92,0.75]	[1.66,3.82]	[-0.03,0.32]
31-36m	3.15	-0.45	-0.7	3.33*	0.16
	[-3.18,9.48]	[-1.87,0.96]	[-2.21,0.80]	[2.22,4.44]	[-0.03,0.34]
16-24m # Female	0.63	-0.16	0.17	-0.05	-0.05
	[-2.96,4.22]	[-1.16,0.84]	[-0.97,1.32]	[-1.02,0.91]	[-0.20,0.10]
25-30m # Female	-2.68	0.23	0.45	-0.6	-0.03
	[-8.24,2.88]	[-1.23,1.69]	[-1.07,1.98]	[-1.90,0.70]	[-0.22,0.15]
31-36m # Female	-2.51	0.54	0.68	-0.29	0.04
	[-9.05,4.02]	[-1.13,2.20]	[-1.03,2.39]	[-1.68,1.10]	[-0.17,0.24]
1st Child			Reference		
	3.26^{+}	-1.04*	-1.26*	-0.83^{+}	-0.07
2-4 children	[-0.01,6.53]	[-1.90,-0.19]	[-2.25,-0.26]	[-1.66,0.00]	[-0.17,0.03]
	4.69^{+}	-1.23*	-2.04*	-1.55*	-0.09
5+ children	[-0.28,9.66]	[-2.45,-0.01]	[-3.45,-0.64]	[-2.64,-0.47]	[-0.22,0.04]
Jan			Reference		
Feb	1.07	-0.01	-0.24	-0.13	0.06*
	[-0.48,2.62]	[-0.51,0.50]	[-0.79,0.30]	[-0.63,0.38]	[0.00,0.12]
Mar	1.94^{+}	-0.31	-0.44	-0.37	0.03
	[-0.29,4.17]	[-0.98,0.36]	[-1.12,0.23]	[-1.04,0.29]	[-0.06,0.12]
Apr	1.46	-0.38	-0.49	-0.2	0.02
	[-0.96,3.88]	[-1.11,0.36]	[-1.24,0.26]	[-0.90,0.50]	[-0.08,0.13]
May	0.96	-0.55	-0.66	-0.57	0
	[-1.86,3.77]	[-1.38,0.29]	[-1.51,0.19]	[-1.45,0.31]	[-0.12,0.11]
Jun	1.62	-0.43	-0.58	-0.27	0.07
	[-1.25,4.48]	[-1.33,0.47]	[-1.52,0.36]	[-1.18,0.64]	[-0.05,0.20]
Jul	1.8	-0.21	-0.03	0.3	0.07
	[-1.04,4.63]	[-1.08,0.66]	[-0.97,0.90]	[-0.62,1.22]	[-0.07,0.22]
Aug	0.22	0.12	-0.16	0.1	0

	[-2.53,2.97]	[-0.68,0.92]	[-1.02,0.69]	[-0.74,0.93]	[-0.11,0.11]
Sep	2.37^{+}	-0.07	-0.29	0.25	-0.01
	[-0.18,4.92]	[-0.82,0.67]	[-1.08,0.49]	[-0.47,0.97]	[-0.09,0.08]
Oct	2.88*	-0.38	-0.45	0.04	0.01
	[0.35,5.42]	[-1.10,0.35]	[-1.19,0.30]	[-0.62,0.70]	[-0.07,0.09]
Nov	0.89	-0.05	-0.29	-0.05	-0.02
	[-1.44,3.21]	[-0.76,0.67]	[-1.04,0.45]	[-0.73,0.63]	[-0.09,0.06]
Dec	-0.54	0.16	0.01	-0.01	-0.07*
	[-2.17,1.08]	[-0.35,0.66]	[-0.51,0.53]	[-0.47,0.45]	[-0.13,-0.00]
Asset	-0.44	-0.09	0.08	-0.21^{+}	-0.02
	[-1.43,0.56]	[-0.33,0.16]	[-0.20,0.37]	[-0.45,0.03]	[-0.05,0.01]
Income	-0.01	0	0	0	0
	[-0.02,0.01]	[-0.00,0.00]	[-0.00,0.01]	[-0.00,0.00]	[-0.00,0.00]
Sanitation Score	0.39	-0.04	-0.01	-0.1	-0.02*
	[-0.44,1.22]	[-0.25,0.16]	[-0.25,0.23]	[-0.30,0.09]	[-0.05,-0.00]
Maternal Education	-0.49	-0.17	-0.15	-0.42*	-0.03*
	[-1.67,0.70]	[-0.46,0.13]	[-0.48,0.19]	[-0.70,-0.14]	[-0.06,-0.00]
Illness	0.01	-0.02	-0.02	-0.02	0
	[-0.07,0.10]	[-0.04,0.01]	[-0.04,0.01]	[-0.04,0.01]	[-0.01,0.00]
Birth Mont/Year	0.1	-0.01	0.01	0.02	0
	[-0.09,0.28]	[-0.06,0.05]	[-0.05,0.07]	[-0.03,0.07]	[-0.00,0.01]
Energy (kcal)	4.18*	-1.11*	-1.62*	-0.41	-0.04
	[1.54,6.82]	[-1.89,-0.33]	[-2.34,-0.90]	[-1.04,0.22]	[-0.14,0.06]
Breast milk in the diet	0.18*	0.02*	0.01*	0.00*	0.00*
	[0.18,0.19]	[0.02,0.02]	[0.01,0.01]	[0.00,0.01]	[0.00,0.00]
Constant	-67.14	10.21	-1.72	-7	-0.16
	[-183.30,49.03]	[-21.92,42.35]	[-36.09,32.66]	[-35.68,21.68]	[-3.64,3.32]
Observations	5443	5443	5443	5443	5443

95% confidence intervals in brackets
$^{+}$ $p < 0.10$, * $p < 0.05$

Table 5-11: Random effects model results of ENSO exposure on nutrient Intakes of children 9-36 months of age

	Vitamin A (µg~RE)	Vitamin C (mg)	Folate (µg)	Vitamin B-12(µg)	Calcium (mg)	Iron (mg)	Zinc (mg)
Neutral				Reference			
Weak El Niño	-15.26	3.71	-1.07	0.06	30.56	0.34	-0.01
	[-62.45,31.94]	[-16.82,24.24]	[-6.46,4.31]	[-0.15,0.28]	[-20.73,81.85]	[-0.66,1.34]	[-0.20,0.17]
Moderate El Niño	27.79	20.63*	4.04	0.28	66.89+	1.29+	0.07
	[-113.49,169.07]	[2.51,38.75]	[-7.59,15.68]	[-0.42,0.99]	[-11.10,144.89]	[-0.06,2.64]	[-0.17,0.32]
Weak La Niña	-3.36	8.82	0.68	-0.01	-82.77*	-1.07*	-0.31*
	[-45.72,38.99]	[-24.18,41.81]	[-5.85,7.20]	[-0.18,0.17]	[-128.08,-37.45]	[-1.81,-0.33]	[-0.50,-0.12]
Moderate La Niña	-33.4	38.46*	-8.26	-0.11	-55.8	-2.10*	-0.13
	[-106.41,39.61]	[16.77,60.15]	[-18.43,1.92]	[-0.43,0.20]	[-155.56,43.96]	[-3.35,-0.84]	[-0.31,0.06]
Strong La Niña	-25.15	-19.5	-2.68	-0.05	-95.54*	-1.97*	-0.14
	[-92.28,41.98]	[-44.41,5.41]	[-11.14,5.79]	[-0.31,0.21]	[-168.27,-22.81]	[-3.08,-0.85]	[-0.34,0.06]
Male				Reference			
Female	-20.62	-1.6	-4.47	-0.15	-7.84	-0.15	-0.01
	[-75.56,34.32]	[-22.85,19.66]	[-10.18,1.24]	[-0.34,0.05]	[-58.46,42.79]	[-1.06,0.77]	[-0.20,0.18]
weak El Niño # Female	-20.98	-14.84	-4.43	-0.2	-27.21	-0.41	-0.14
	[-78.16,36.21]	[-51.66,21.97]	[-11.24,2.39]	[-0.44,0.04]	[-96.36,41.94]	[-1.76,0.94]	[-0.38,0.09]
moderate El Niño # Female	-13.19	-16.12	-10.19	-0.49	-82.31	-1.57+	-0.32+
	[-161.20,134.83]	[-41.85,9.62]	[-22.87,2.48]	[-1.19,0.21]	[-182.13,17.52]	[-3.29,0.14]	[-0.66,0.01]
weak La Niña # Female	-23.45	11.5	2.41	0.07	49.31	0.11	0.32*
	[-80.06,33.17]	[-38.86,61.85]	[-5.71,10.54]	[-0.16,0.29]	[-11.77,110.38]	[-0.88,1.11]	[0.09,0.55]
moderate La Niña # Female	0.61	-1.63	4.46	0.02	57.41	1.28	0.15
	[-85.21,86.42]	[-24.13,20.88]	[-7.10,16.02]	[-0.31,0.34]	[-62.93,177.75]	[-0.55,3.11]	[-0.12,0.41]
strong La Niña # Female	-25	-1.64	0.3	0.01	94.52*	1.18	0.2

	[-100.84,50.83]	[-33.73,30.44]	[-10.59,11.20]	[-0.28,0.30]	[7.18,181.86]	[-0.24,2.59]	[-0.08,0.49]
9-15m				Reference			
16-24m	-67.37*	30.02*	-0.23	0	-88.68*	-1.18*	0.13
	[-116.70,-18.05]	[7.89,52.15]	[-5.87,5.41]	[-0.17,0.18]	[-142.09,-35.27]	[-2.00,-0.35]	[-0.05,0.31]
25-30m	-144.27*	-2.85	-11.48*	-0.17	-204.65*	-2.36*	-0.57*
	[-198.12,-90.41]	[-34.98,29.29]	[-19.37,-3.58]	[-0.40,0.07]	[-281.20,-128.09]	[-3.69,-1.03]	[-0.83,-0.31]
31-36m	-190.28*	20.76	-18.05*	-0.24+	-258.96*	-3.26*	-0.72*
	[-244.40,-136.17]	[-30.36,71.88]	[-28.58,-7.53]	[-0.49,0.01]	[-343.71,-174.22]	[-4.76,-1.76]	[-1.09,-0.35]
16-24m # Female	-67.37*	30.02*	-0.23	0	-88.68*	-1.18*	0.13
	[-116.70,-18.05]	[7.89,52.15]	[-5.87,5.41]	[-0.17,0.18]	[-142.09,-35.27]	[-2.00,-0.35]	[-0.05,0.31]
25-30m # Female	58.43+	43.56*	7.34+	0.18	38.72	0.89	0.21
	[-7.79,124.66]	[0.79,86.34]	[-1.29,15.96]	[-0.10,0.46]	[-41.93,119.37]	[-0.54,2.32]	[-0.10,0.51]
31-36m # Female	73.41*	55.93	12.91*	0.32*	-0.12	0.3	0.1
	[10.32,136.50]	[-18.54,130.40]	[3.99,21.83]	[0.02,0.62]	[-76.79,76.55]	[-1.00,1.60]	[-0.21,0.40]
Only child				Reference			
2-4 children	-6.13	-9.05	0.96	-0.11	-26.41	-0.29	-0.12
	[-42.01,29.75]	[-31.85,13.75]	[-3.86,5.78]	[-0.24,0.02]	[-67.69,14.87]	[-0.92,0.34]	[-0.29,0.04]
5+ children	6.57	-26.62+	5.18	-0.13	22.81	0.68	-0.01
	[-49.37,62.50]	[-58.22,4.98]	[-2.36,12.71]	[-0.31,0.06]	[-46.40,92.01]	[-0.47,1.82]	[-0.26,0.23]
Jan				Reference			
Feb	14.76	-79.48*	2.90*	-0.03	28.22*	0.66*	0.07+
	[-8.50,38.03]	[-104.47,-54.49]	[0.13,5.68]	[-0.12,0.06]	[6.68,49.76]	[0.23,1.09]	[-0.01,0.14]
Mar	-25.22	-118.99*	0.38	-0.16*	46.27*	1.13*	0.05
	[-59.00,8.57]	[-152.32,-85.67]	[-3.79,4.56]	[-0.28,-0.04]	[12.11,80.44]	[0.43,1.83]	[-0.06,0.16]
Apr	-36.66*	-126.99*	-1.65	-0.20*	50.58*	1.23*	0.03
	[-71.76,-1.56]	[-162.64,-91.34]	[-6.54,3.24]	[-0.32,-0.07]	[12.62,88.55]	[0.50,1.96]	[-0.10,0.16]
May	-24.84	-123.33*	-2.17	-0.12	26.41	0.51	0.03
	[-60.61,10.92]	[-155.91,-90.74]	[-7.19,2.84]	[-0.27,0.03]	[-13.18,66.00]	[-0.21,1.22]	[-0.15,0.20]
Jun	-15.48	-127.24*	-2.92	-0.02	5.92	0.26	-0.02
	[-51.22,20.26]	[-159.37,-95.10]	[-7.85,2.01]	[-0.18,0.14]	[-32.73,44.57]	[-0.38,0.90]	[-0.19,0.15]

Jul	-47.36*	-132.41*	-5.94*	-0.02	-6.74	-0.14	-0.06
	[-85.82,-8.91]	[-166.65,-98.16]	[-11.12,-0.76]	[-0.19,0.16]	[-41.78,28.30]	[-0.70,0.42]	[-0.22,0.10]
Aug	-41.57*	-117.21*	-3.54	-0.02	31.03^{+}	0.53^{+}	0.08
	[-78.14,-5.00]	[-150.46,-83.97]	[-8.69,1.61]	[-0.18,0.13]	[-4.24,66.31]	[-0.06,1.13]	[-0.09,0.26]
Sep	-41.49*	-96.68*	-2.9	-0.07	34.72*	0.74*	0.01
	[-76.74,-6.24]	[-131.38,-61.98]	[-7.47,1.67]	[-0.21,0.06]	[0.91,68.53]	[0.10,1.37]	[-0.12,0.15]
Oct	-27.76	-86.79*	-1.15	0	12.05	0.44	0
	[-64.60,9.08]	[-123.61,-49.98]	[-5.79,3.48]	[-0.13,0.13]	[-21.92,46.02]	[-0.19,1.07]	[-0.12,0.12]
Nov	-20.57	-23.9	-2.51	-0.02	16.77	0.41^{+}	0.13^{+}
	[-52.54,11.39]	[-65.04,17.25]	[-6.61,1.59]	[-0.14,0.10]	[-6.15,39.69]	[-0.00,0.82]	[-0.02,0.28]
Dec	-31.44*	36.27*	-4.57*	-0.09^{+}	17.24^{+}	0.23	0.08
	[-59.19,-3.69]	[8.57,63.96]	[-7.83,-1.31]	[-0.19,0.01]	[-0.43,34.90]	[-0.07,0.54]	[-0.02,0.18]
Assets	3.26	-0.86	-0.04	-0.02	5.9	-0.12	0.03
	[-6.41,12.92]	[-7.08,5.35]	[-1.45,1.37]	[-0.05,0.02]	[-5.18,16.98]	[-0.31,0.07]	[-0.02,0.07]
Income (USD)	-0.09	-0.08	-0.02^{+}	0	-0.08	0	0
	[-0.27,0.08]	[-0.21,0.05]	[-0.04,0.00]	[-0.00,0.00]	[-0.30,0.13]	[-0.01,0.00]	[-0.00,0.00]
Sanitation Score	-6.6	2.44	-0.33	-0.01	1.99	-0.07	-0.01
	[-14.94,1.74]	[-3.87,8.74]	[-1.55,0.89]	[-0.04,0.03]	[-9.31,13.29]	[-0.24,0.09]	[-0.06,0.03]
Maternal Education	6.3	3.18	0.83	-0.01	6.06	-0.05	0.02
	[-6.72,19.32]	[-2.55,8.92]	[-0.94,2.59]	[-0.05,0.03]	[-11.91,24.04]	[-0.29,0.20]	[-0.04,0.07]
Illness	0.44	-0.34	-0.05	0	0.62	0.01	0
	[-0.93,1.81]	[-1.23,0.54]	[-0.21,0.11]	[-0.01,0.00]	[-0.63,1.87]	[-0.02,0.03]	[-0.01,0.00]
Birth month-year	-0.33	0.39	0.03	0	-3.98*	-0.07*	-0.01
	[-2.27,1.62]	[-0.76,1.55]	[-0.25,0.30]	[-0.01,0.01]	[-6.62,-1.34]	[-0.11,-0.03]	[-0.02,0.00]
Energy	0.33*	0.05*	0.06*	0.00*	0.42*	0.01*	0.00*
	[0.29,0.37]	[0.03,0.08]	[0.05,0.07]	[0.00,0.00]	[0.33,0.51]	[0.00,0.01]	[0.00,0.00]
Breast milk in the diet	-5.52	-6.49	-0.3	-0.04	-35.43	0.02	-0.09
	[-39.47,28.43]	[-24.29,11.31]	[-5.23,4.63]	[-0.17,0.09]	[-78.84,7.97]	[-0.70,0.73]	[-0.26,0.08]

Constant	272.93	-121.71	1.22	-0.75	2,405.85*	45.24*	4.64
	[-916.95,1,462.82]	[-837.89,594.48]	[-168.87,171.32]	[-5.44,3.93]	[789.17,4,022.53]	[22.23,68.24]	[-1.56,10.85]
Observations	5443	5443	5443	5443	5443	5443	5443

Table 5-12: Random effects model results on NAR (not truncated at 1.0)

NAR	*Random Effects*						
	Vitamin A	Vitamin C	Calcium	Iron	Folate	Zinc	Vitamin B12
Neutral				Reference			
weak El Niño	-0.19+	0.99	0.05	0.03	0.01	0	0.11
	[-0.40,0.02]	[-0.32,2.29]	[-0.07,0.16]	[-0.05,0.11]	[-0.05,0.06]	[-0.02,0.02]	[-0.15,0.37]
moderate El Niño	-0.22	0.34	0.11	0.10+	0.06	0.01	0.44
	[-0.65,0.20]	[-1.25,1.93]	[-0.08,0.29]	[-0.01,0.21]	[-0.08,0.20]	[-0.02,0.04]	[-0.39,1.26]
weak La Niña	0.02	1.75	-0.19*	-0.08*	0.05	-0.04*	-0.03
	[-0.23,0.28]	[-1.28,4.79]	[-0.30,-0.09]	[-0.14,-0.02]	[-0.03,0.13]	[-0.06,-0.01]	[-0.25,0.20]
moderate La Niña	-0.62*	0.09	-0.15	-0.19*	-0.12	-0.02	-0.18
	[-1.07,-0.16]	[-2.11,2.30]	[-0.45,0.14]	[-0.27,-0.10]	[-0.28,0.04]	[-0.04,0.00]	[-0.61,0.25]
strong La Niña	-0.26	-2.17+	-0.24*	-0.18*	0.24*	-0.02	0.07
	[-0.76,0.24]	[-4.53,0.19]	[-0.43,-0.05]	[-0.27,-0.09]	[0.07,0.41]	[-0.04,0.01]	[-0.36,0.51]
Male				Reference			
Female	-0.23	0.08	-0.04	-0.01	-0.06	0	-0.30+
	[-0.70,0.24]	[-2.29,2.45]	[-0.21,0.12]	[-0.08,0.06]	[-0.19,0.08]	[-0.02,0.02]	[-0.64,0.04]
weak El Niño # Female	0.11	-0.32	-0.05	-0.03	-0.04	-0.02	-0.24

	[-0.13,0.36]	[-2.26,1.62]	[-0.19,0.10]	[-0.15,0.08]	[-0.11,0.03]	[-0.04,0.01]	[-0.53,0.06]
moderate El Niño # Female	0.36	-0.28	-0.15	-0.12+	-0.08	-0.04+	-0.63
	[-0.20,0.92]	[-2.05,1.49]	[-0.37,0.07]	[-0.26,0.02]	[-0.23,0.08]	[-0.08,0.00]	[-1.45,0.19]
weak La Niña # Female	-0.05	1.11	0.15*	0	0.02	0.04*	0.17
	[-0.43,0.33]	[-3.01,5.23]	[0.00,0.29]	[-0.08,0.08]	[-0.11,0.15]	[0.01,0.07]	[-0.13,0.47]
moderate La Niña # Female	-0.01	-0.47	0.21	0.10+	0.13	0.01	0.09
	[-0.63,0.61]	[-3.90,2.96]	[-0.22,0.64]	[-0.01,0.20]	[-0.14,0.40]	[-0.02,0.05]	[-0.40,0.58]
strong La Niña # Female	-0.37	0.37	0.22+	0.11+	-0.1	0.02	0.12
	[-0.99,0.25]	[-3.44,4.18]	[-0.04,0.48]	[-0.00,0.23]	[-0.42,0.22]	[-0.01,0.06]	[-0.46,0.71]
9-15m				Reference			
16-24m	-0.48*	2.48*	-0.30*	-0.06+	-0.34*	0.02+	-0.49*
	[-0.80,-0.16]	[0.24,4.72]	[-0.46,-0.14]	[-0.13,0.00]	[-0.43,-0.26]	[-0.00,0.04]	[-0.75,-0.22]
25-30m	-0.81*	0.58	-0.56*	-0.16*	-0.40*	-0.07*	-0.63*
	[-1.14,-0.48]	[-1.60,2.76]	[-0.77,-0.36]	[-0.27,-0.05]	[-0.49,-0.30]	[-0.10,-0.04]	[-0.96,-0.31]
31-36m	-0.92*	1.11	-0.68*	-0.23*	-0.44*	-0.09*	-0.69*
	[-1.22,-0.62]	[-1.43,3.65]	[-0.90,-0.46]	[-0.36,-0.11]	[-0.55,-0.33]	[-0.13,-0.04]	[-1.02,-0.36]
16-24m # Female	0.1	-0.73	0.07	0.04	0.02	-0.02	0.23
	[-0.33,0.54]	[-3.60,2.14]	[-0.11,0.25]	[-0.05,0.13]	[-0.11,0.15]	[-0.05,0.01]	[-0.11,0.58]
25-30m # Female	0.36	1.49	0.11	0.07	0.09	0.02	0.35+
	[-0.12,0.84]	[-1.30,4.28]	[-0.10,0.32]	[-0.04,0.19]	[-0.05,0.22]	[-0.01,0.06]	[-0.05,0.75]
31-36m # Female	0.33	2.04	0.03	0.02	0.12	0.01	0.50*
	[-0.13,0.78]	[-1.36,5.44]	[-0.18,0.23]	[-0.08,0.13]	[-0.02,0.26]	[-0.03,0.05]	[0.09,0.91]
Only child				Reference			
2-4 children	-0.01	-0.5	-0.06	-0.02	-0.01	-0.01	-0.13
	[-0.22,0.20]	[-1.82,0.81]	[-0.15,0.04]	[-0.07,0.03]	[-0.06,0.05]	[-0.03,0.00]	[-0.30,0.04]
5+ children	0.06	-1.3	0.08	0.06	0.04	0	-0.17
	[-0.27,0.40]	[-3.15,0.55]	[-0.09,0.24]	[-0.04,0.15]	[-0.03,0.12]	[-0.03,0.03]	[-0.40,0.06]

Jan				Reference			
Feb	0.1	-5.59*	0.05*	0.06*	-0.02	0.01+	-0.10+
	[-0.06,0.26]	[-7.48,-3.71]	[0.00,0.10]	[0.02,0.09]	[-0.06,0.02]	[-0.00,0.02]	[-0.21,0.01]
Mar	0	-7.74*	0.10*	0.10*	0	0.01	-0.21*
	[-0.22,0.21]	[-9.97,-5.51]	[0.02,0.18]	[0.04,0.15]	[-0.06,0.06]	[-0.01,0.02]	[-0.39,-0.04]
Apr	-0.1	-7.68*	0.11*	0.10*	-0.01	0	-0.26*
	[-0.31,0.10]	[-10.13,-5.24]	[0.03,0.20]	[0.04,0.16]	[-0.07,0.06]	[-0.01,0.02]	[-0.43,-0.09]
May	-0.12	-8.30*	0.08	0.04	-0.01	0	-0.18+
	[-0.30,0.06]	[-10.67,-5.94]	[-0.02,0.17]	[-0.02,0.10]	[-0.07,0.04]	[-0.02,0.03]	[-0.36,0.00]
Jun	-0.1	-8.76*	0.03	0.02	-0.02	0	-0.06
	[-0.28,0.08]	[-11.01,-6.50]	[-0.07,0.12]	[-0.03,0.07]	[-0.08,0.05]	[-0.02,0.02]	[-0.26,0.14]
Jul	-0.18+	-8.58*	0.01	-0.01	-0.01	-0.01	-0.05
	[-0.39,0.02]	[-10.84,-6.32]	[-0.08,0.10]	[-0.06,0.03]	[-0.09,0.06]	[-0.03,0.01]	[-0.27,0.17]
Aug	-0.16	-8.77*	0.10*	0.04+	0	0.01	-0.04
	[-0.36,0.05]	[-11.17,-6.36]	[0.01,0.18]	[-0.01,0.09]	[-0.06,0.07]	[-0.01,0.03]	[-0.24,0.15]
Sep	-0.15	-7.47*	0.09*	0.06*	0.04	0	-0.05
	[-0.39,0.09]	[-9.75,-5.18]	[0.01,0.17]	[0.01,0.11]	[-0.04,0.11]	[-0.01,0.02]	[-0.25,0.15]
Oct	-0.05	-6.96*	0.04	0.03	0.06	0	0.04
	[-0.30,0.20]	[-9.30,-4.62]	[-0.04,0.12]	[-0.02,0.08]	[-0.02,0.13]	[-0.01,0.02]	[-0.17,0.24]
Nov	-0.03	-3.36*	0.07*	0.03	0.04	0.02+	0.03
	[-0.25,0.19]	[-5.87,-0.85]	[0.01,0.13]	[-0.01,0.06]	[-0.02,0.11]	[-0.00,0.04]	[-0.15,0.21]
Dec	-0.09	1.47	0.06*	0.01	0	0.01	-0.08
	[-0.28,0.10]	[-0.36,3.30]	[0.01,0.11]	[-0.01,0.04]	[-0.04,0.03]	[-0.00,0.02]	[-0.24,0.08]
Asset	-0.01	0.08	0.01	-0.01	0	0	-0.02
	[-0.07,0.05]	[-0.30,0.46]	[-0.02,0.03]	[-0.03,0.01]	[-0.01,0.02]	[-0.00,0.01]	[-0.07,0.03]
Income	0	0	0	0	-0.00+	0	0
	[-0.00,0.00]	[-0.01,0.00]	[-0.00,0.00]	[-0.00,0.00]	[-0.00,0.00]	[-0.00,0.00]	[-0.00,0.00]
Sanitation	-0.03	0.28	0	0	0	0	-0.01
	[-0.08,0.02]	[-0.08,0.65]	[-0.03,0.03]	[-0.02,0.01]	[-0.02,0.01]	[-0.01,0.00]	[-0.05,0.03]

Maternal Education	0.03	0.26	0	0	0.01	0	0
	[-0.05,0.11]	[-0.19,0.71]	[-0.04,0.05]	[-0.02,0.02]	[-0.01,0.03]	[-0.01,0.01]	[-0.06,0.05]
Illness	0.01	-0.04	0	0	0	0	0
	[-0.00,0.01]	[-0.09,0.01]	[-0.00,0.01]	[-0.00,0.00]	[-0.00,0.00]	[-0.00,0.00]	[-0.01,0.01]
Birth month-year	0	0.03	-0.01*	-0.01*	0.00*	0	0.01
	[-0.01,0.01]	[-0.04,0.10]	[-0.01,-0.00]	[-0.01,-0.00]	[0.00,0.01]	[-0.00,0.00]	[-0.00,0.02]
Energy	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]
Breast milk in the Diet	1.22*	7.12*	0.10*	0	0.25*	0.01	-0.06
	[1.01,1.43]	[5.56,8.69]	[0.00,0.20]	[-0.06,0.06]	[0.20,0.30]	[-0.01,0.03]	[-0.21,0.10]
Constant	-1.77	-15.25	4.60*	3.97*	-1.84*	0.54	-2.99
	[-8.22,4.68]	[-57.54,27.04]	[1.03,8.16]	[2.09,5.85]	[-3.40,-0.28]	[-0.21,1.30]	[-8.56,2.58]
Observations	5443	5443	5443	5443	5443	5443	5443

Table 5-13: Random effects model results of ENSO exposure on NAR bounded at 1.0 among children 9-36 months of age

NAR bounded at 1.0	*Random Effects Model*						
	Vitamin A	Vitamin C	Calcium	Iron	Folate	Zinc	Vitamin B12
Neutral				Reference			
weak El Niño	-0.003	0.038*	-0.017	-0.005	0.007	-0.003	0.01
	[-0.042,0.035]	[0.007,0.068]	[-0.056,0.021]	[-0.033,0.023]	[-0.022,0.036]	[-0.021,0.014]	[-0.024,0.043]
moderate El Niño	-0.03	0.02	0.029	0.02	0.045	0.01	0.005
	[-0.105,0.045]	[-0.033,0.072]	[-0.040,0.098]	[-0.025,0.066]	[-0.014,0.103]	[-0.019,0.039]	[-0.066,0.077]
weak La Niña	-0.012	0.027+	-0.042+	-0.034*	0.038*	-0.026*	0.033+
	[-0.048,0.024]	[-0.001,0.056]	[-0.084,0.001]	[-0.063,-0.004]	[0.004,0.073]	[-0.044,-0.008]	[-0.004,0.071]

moderate La Niña	-0.025	0	-0.116*	-0.089*	-0.004	-0.014	-0.054
	[-0.125,0.074]	[-0.083,0.083]	[-0.198,-0.034]	[-0.144,-0.033]	[-0.110,0.101]	[-0.037,0.008]	[-0.165,0.058]
strong La Niña	-0.01	0.016	-0.099*	-0.108*	0.150*	-0.023*	0.076
	[-0.086,0.066]	[-0.051,0.083]	[-0.182,-0.016]	[-0.156,-0.060]	[0.079,0.221]	[-0.046,-0.001]	[-0.037,0.188]
Male				Reference			
Female	-0.006	0.007	0.004	-0.022	-0.023	-0.003	-0.029
	[-0.057,0.044]	[-0.034,0.047]	[-0.053,0.062]	[-0.062,0.019]	[-0.066,0.021]	[-0.023,0.016]	[-0.090,0.032]
weak El Niño # Female	-0.037	-0.056*	0.02	-0.003	-0.039^{+}	-0.012	-0.019
	[-0.089,0.014]	[-0.100,-0.013]	[-0.030,0.070]	[-0.038,0.033]	[-0.078,0.001]	[-0.035,0.010]	[-0.063,0.025]
moderate El Niño # Female	-0.003	-0.058^{+}	-0.049	-0.033	-0.055	-0.041*	-0.065
	[-0.092,0.086]	[-0.126,0.011]	[-0.137,0.039]	[-0.094,0.029]	[-0.128,0.018]	[-0.078,-0.004]	[-0.159,0.029]
weak La Niña # Female	-0.008	-0.004	0.065*	0.033^{+}	-0.001	0.034*	0.006
	[-0.060,0.045]	[-0.047,0.039]	[0.004,0.126]	[-0.005,0.071]	[-0.051,0.049]	[0.009,0.059]	[-0.049,0.060]
moderate La Niña # Female	-0.038	0.009	0.104	0.055	0.068	0.007	-0.044
	[-0.189,0.114]	[-0.100,0.118]	[-0.037,0.245]	[-0.027,0.137]	[-0.085,0.222]	[-0.024,0.037]	[-0.220,0.132]
strong La Niña # Female	-0.006	-0.037	0.092	0.074^{+}	-0.037	0.025	0.007
	[-0.112,0.101]	[-0.125,0.052]	[-0.041,0.226]	[-0.014,0.161]	[-0.167,0.093]	[-0.009,0.058]	[-0.154,0.168]
9-15m				Reference			
16-24m	-0.036^{+}	0.011	-0.069*	-0.002	-0.142*	0.027*	-0.023
	[-0.075,0.003]	[-0.017,0.038]	[-0.118,-0.020]	[-0.035,0.031]	[-0.174,-0.109]	[0.007,0.047]	[-0.064,0.019]
25-30m	-0.108*	-0.027	-0.167*	-0.060*	-0.164*	-0.040*	-0.026
	[-0.159,-0.057]	[-0.064,0.010]	[-0.226,-0.108]	[-0.107,-0.013]	[-0.205,-0.122]	[-0.065,-0.015]	[-0.075,0.024]
31-36m	-0.180*	-0.063*	-0.181*	-0.078*	-0.182*	-0.047*	-0.037
	[-0.234,-0.126]	[-0.105,-0.022]	[-0.245,-0.117]	[-0.129,-0.028]	[-0.226,-0.138]	[-0.076,-0.018]	[-0.091,0.018]
16-24m # Female	0.005	-0.02	0.011	0.006	0.01	-0.011	0.050^{+}
	[-0.048,0.059]	[-0.059,0.020]	[-0.053,0.075]	[-0.033,0.046]	[-0.031,0.051]	[-0.034,0.011]	[-0.008,0.107]
25-30m # Female	0.032	0.016	0.036	0.035	0.045^{+}	0.019	0.034

	[-0.033,0.097]	[-0.034,0.066]	[-0.038,0.110]	[-0.015,0.084]	[-0.006,0.096]	[-0.009,0.048]	[-0.029,0.098]
31-36m # Female	0.085*	0.074*	0.002	0.027	0.063*	0.006	0.039
	[0.020,0.150]	[0.025,0.123]	[-0.075,0.079]	[-0.025,0.079]	[0.009,0.117]	[-0.024,0.037]	[-0.030,0.107]
Only Child				Reference			
2-4 Children	0	0.012	0.004	-0.003	0.008	-0.011	-0.024
	[-0.035,0.035]	[-0.020,0.044]	[-0.036,0.044]	[-0.028,0.022]	[-0.020,0.036]	[-0.028,0.006]	[-0.063,0.015]
5+ Children	0.013	-0.007	0.048	0.036+	0.049*	0.001	-0.035
	[-0.039,0.065]	[-0.051,0.036]	[-0.011,0.107]	[-0.003,0.074]	[0.008,0.091]	[-0.023,0.026]	[-0.086,0.017]
Jan				Reference			
Feb	-0.016	-0.022*	0.002	0.025*	-0.01	0.005	-0.025+
	[-0.042,0.011]	[-0.042,-0.002]	[-0.018,0.022]	[0.011,0.038]	[-0.030,0.010]	[-0.003,0.013]	[-0.054,0.003]
Mar	-0.045*	-0.018	0.022	0.035*	-0.009	0.004	-0.02
	[-0.077,-0.013]	[-0.044,0.007]	[-0.006,0.050]	[0.014,0.056]	[-0.037,0.018]	[-0.009,0.016]	[-0.055,0.014]
Apr	-0.044*	-0.014	0.02	0.029*	-0.012	0	-0.013
	[-0.077,-0.010]	[-0.043,0.016]	[-0.011,0.051]	[0.007,0.051]	[-0.042,0.018]	[-0.012,0.012]	[-0.047,0.022]
May	-0.037*	-0.025+	0.015	0.007	0.006	0.001	-0.007
	[-0.074,-0.001]	[-0.055,0.004]	[-0.022,0.051]	[-0.019,0.033]	[-0.025,0.036]	[-0.014,0.015]	[-0.043,0.029]
Jun	-0.045*	-0.026+	-0.004	0.01	-0.009	0.001	0.016
	[-0.080,-0.011]	[-0.056,0.004]	[-0.038,0.030]	[-0.015,0.035]	[-0.039,0.021]	[-0.015,0.017]	[-0.020,0.052]
Jul	-0.065*	-0.018	0.02	0.008	-0.027+	-0.002	0.032+
	[-0.102,-0.028]	[-0.052,0.015]	[-0.016,0.056]	[-0.018,0.034]	[-0.056,0.003]	[-0.020,0.015]	[-0.006,0.069]
Aug	-0.055*	-0.013	0.050*	0.032*	-0.005	0.005	0.024
	[-0.092,-0.019]	[-0.042,0.016]	[0.016,0.083]	[0.008,0.055]	[-0.034,0.025]	[-0.012,0.022]	[-0.013,0.061]
Sep	-0.066*	0.01	0.030+	0.030*	0.008	0.002	0.014
	[-0.101,-0.031]	[-0.017,0.036]	[-0.004,0.063]	[0.009,0.052]	[-0.019,0.035]	[-0.012,0.016]	[-0.021,0.050]
Oct	-0.038*	0.002	0.018	0.015	0.014	0.002	0.021
	[-0.072,-0.004]	[-0.026,0.029]	[-0.012,0.048]	[-0.005,0.035]	[-0.014,0.041]	[-0.012,0.015]	[-0.014,0.056]
Nov	-0.033*	-0.005	0.032*	0.026*	0.01	0.008	0.023
	[-0.065,-0.001]	[-0.032,0.022]	[0.004,0.060]	[0.007,0.045]	[-0.017,0.037]	[-0.005,0.021]	[-0.009,0.056]
Dec	-0.02	0.011	0.027*	0.014+	0.002	0.008	0.01

	[-0.045,0.006]	[-0.009,0.030]	[0.006,0.049]	[-0.002,0.030]	[-0.019,0.022]	[-0.002,0.018]	[-0.016,0.035]
Asset	0.006	0	0.007	-0.005	0.001	0.003	-0.010+
	[-0.004,0.017]	[-0.010,0.010]	[-0.005,0.019]	[-0.012,0.002]	[-0.008,0.009]	[-0.002,0.008]	[-0.022,0.001]
Income (USD)	0	0	0	0	0	0	0
	[-0.000,0.000]	[-0.000,0.000]	[-0.000,0.000]	[-0.000,0.000]	[-0.000,0.000]	[-0.000,0.000]	[-0.000,0.000]
Sanitation Score	-0.006	-0.005	0.006	-0.003	-0.002	0	-0.001
	[-0.015,0.003]	[-0.014,0.003]	[-0.006,0.017]	[-0.010,0.004]	[-0.009,0.005]	[-0.005,0.004]	[-0.010,0.009]
Maternal education	0.012*	0.007	0.017*	-0.004	0.006	0.001	-0.003
	[0.000,0.024]	[-0.003,0.017]	[0.003,0.030]	[-0.014,0.005]	[-0.004,0.015]	[-0.004,0.007]	[-0.016,0.009]
Illness	0	0	0.002*	0.001	0.001	0	0
	[-0.001,0.001]	[-0.001,0.001]	[0.000,0.003]	[-0.000,0.001]	[-0.000,0.002]	[-0.001,0.000]	[-0.001,0.002]
Birth Month Year	-0.001	0.002*	-0.002	-0.002*	0.002*	-0.001	0.001
	[-0.003,0.001]	[0.000,0.004]	[-0.004,0.001]	[-0.003,-0.000]	[0.000,0.003]	[-0.002,0.000]	[-0.001,0.003]
Energy	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
	[0.000,0.000]	[0.000,0.000]	[0.000,0.000]	[0.000,0.000]	[0.000,0.000]	[0.000,0.000]	[0.000,0.000]
Breast milk in the Diet	0.288*	0.175*	0.039*	-0.01	0.141*	-0.002	-0.065*
	[0.257,0.319]	[0.150,0.200]	[0.003,0.074]	[-0.035,0.015]	[0.116,0.166]	[-0.017,0.014]	[-0.099,-0.031]
Constant	0.75	-0.731	1.171	1.208*	-0.819	0.418	0.043
	[-0.468,1.969]	[-1.949,0.488]	[-0.329,2.670]	[0.207,2.209]	[-1.828,0.189]	[-0.223,1.059]	[-1.256,1.342]
Observations	5443	5443	5443	5443	5443	5443	5443

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Chapter 6 : Discussion of the results

The three set of analyses from this dissertation presents evidence for linkages between climate and the food system. In particular, they illustrated how these macro and meso level environmental and economic factors translated to differences in food prices and to meal patterns, dietary diversity, nutrient intake, and adequacy. To my knowledge, this is the first study to examine the associations in a single setting, especially in a vulnerable group of children under five years of age. It includes monthly climate data on Multivariate ENSO Index (MEI), thrice weekly food prices from the local province of Loreto from 2009-2015, Peru, and daily river discharge data from river Nanay from 1960-2015. These three datasets complement an ongoing birth cohort study that was initiated in 2009, where dietary intake was characterized monthly using the 24-hour recall method among 252 children over a 28-month period. This chapter summarizes the findings from the analyses and discusses the potential implications for policies and programs in Peru, as well as other countries that are affected by the ENSO teleconnections. Key findings from these three papers are summarized in Table 6-1.

Summary of Findings

The first aim of the study had two objectives. First, it explored linkages between ENSO and river levels using various ENSO indices (SOI, ONI, MEI). Second, it investigated the associations between ENSO and river levels on regional food prices. For the first objective, relationships between ENSO indices and daily level of river Nanay from 1969-2015 were examined. This analysis was undertaken for several reasons. First, it would inform with respect to the appropriate indices to use for subsequent analyses, and second to confirm the findings of previous research done in this region, which found that river discharges in the western Amazon are affected by ENSO patterns. The river Nanay has a unimodal peak in April, and although these yearly maximums occurred 12 days earlier under El Niño conditions and 18 days later during La Niña conditions, there were no significant differences. However, we identified that during El Niño conditions, the maximum was suppressed during the wet season (February to June), and higher flow was observed during the dry season (July to November). During La Niña, there is an opposite effect such that higher than average flows are observed during wet seasons, and river levels are suppressed in the dry season. Overall, across all three indices, the models indicated a general reduction of river discharge by all severity categories of El Niño. However, for La Niña, ONI models indicated positive flows, SOI indicated negative flows, and MEI indicated no significant differences in flow levels. Models with variables to characterize severity (weak, moderate, strong, very strong) were parsimonious compared to models without severity. Among the severity models, MEI index showed better fit as assessed by the AIC criteria. Overall, from these analyses, we confirmed previously established findings in the regions and found that MEI best captured the river flow of the Nanay river. In addition, the severity of ENSO conditions affected seasonal discharge. The results from this analyses informed variable selection for food prices, dietary and nutrient intake.

The second objective of the first paper examined associations between ENSO and regional food prices of Loreto, Peru, for rice, white sugar, yucca, plantain and eggs. The prices were recorded every two days and were extracted from 2008 to 2015 to cover the same period as the river discharge data. Using vector autoregressive models, temporal effects of rivers levels, season, and ENSO on food prices were established. Models with ENSO severity variable were the most parsimonious. Yucca, sugar, and eggs were the most affected by ENSO, river level, and seasonality, while the rice prices were the most resistant to these factors. This may be due to that national policies in place to subsidize rice were effective compared to locally produced yucca, sugar, eggs, and plantains, which may be subject to local conditions. Impulse Response Functions indicated that the impact of river level on yucca, plantain, and rice prices was carried over to subsequent periods. Yucca prices also showed initial volatility or "up-down" effects with both ENSO and river level shocks. Taken together, these analyses revealed that ENSO and river discharge are highly associated (R^2 >0.70) and that ENSO had direct and indirect pathways (local ecology) of affecting food prices. This could be due to several reasons. First, river levels affect the food economy as it is the main source of transportation in Iquitos. Second, river levels also affect livelihood practices as riparian communities depend upon forest products, fishing and other natural resources for income.

Shown in Table 6-2 are the summary of coefficients examining the ENSO exposure on various measures of dietary quality captured in the second and third aims of this thesis. Models accounted for child-level factors such as age, gender, parity, breastfeeding status, energy intake, morbidity, and household-level factors such as ownership of assets and maternal education. ENSO severity with a gender interaction term was used to identify associations. Commonly consumed food groups included grains/tubers, fruits, and vegetables, meat, dairy and eggs. Girls had slightly higher consumption of meals with dairy compared to boys. There were strong seasonal trends for animal source foods, particularly fish, poultry, and dairy. Fish seasonality is explained by fish availability (higher between June to September) in the rivers. During the months of low fish availability, there is higher consumption of meals with poultry, which resulted in the seasonal intake of poultry. Dairy seasonality was characterized by increased intakes every three months.

ENSO exposure affected frequency of food consumption patterns. Under weak El Niño, frequency of meals with poultry increased which corresponded to the increases in meat/fish/poultry protein. Under moderate El Niño, there were reduction with frequency of meals with fish and plantains, which corresponded to lower fish intake (by 19 grams), and lower energy intake (by 80 kcal). Under weak La Niña, there was an overall increase in frequency of meals with meat, poultry, plantains, which corresponded to increased energy intake (85 kcal) but was inconsistent with lower intake of protein, animal source protein, calcium, iron and zinc. The inconsistency could be attributed to the fact that both protein and animal source protein variables include dairy, which were higher during this period (but not statistically significant). Under moderate La Niña, there was a reduction in frequency of meals with grains, rice, sugar, which did not translate to differences in the actual amount of rice or sugar consumed, nor a reduction in overall energy intake. This is likely because of the small sample size (n=71 dietary recalls) observed under moderate La Niña. Under strong La Niña, frequency of meals with grains, dairy and yucca reduced, however, frequency of meals with plantains increased. This is likely due to substitution of common staples, especially grains with plantains. The 18% reduction in consumption of meals with dairy under these conditions also appropriately corresponded to 95 grams reduction in overall calcium intake. Generally, under La Niña phases, intakes of calcium, iron and zinc were lower, and accordingly, lower NAR for those nutrients but these effects were not observed for girls.

Girls generally consumed more meals with rice and fewer meals with yucca compared to boys. The reduction in yucca meals corresponded to reduction in amount consumed. However, under La Niña, these associations reversed where girls consumed more yucca. In an earlier mixed method food security study conducted in this community, substitution of rice with cheaper options such as yucca was identified as a common practice. For comparison purposes, we ran a fixed effects model to for account for omitted variable bias (such as food prices in the community, cumulative exposure of ENSO, food trade, etc.), and we found the similar magnitude of effect sizes and gender interactions, which reaffirmed the findings in these models.

There were negative associations of asset ownership with amounts consumed of yucca, fish, and rice. As mentioned earlier, yucca is a common substitute for staples (rice or noodles) among food-insecure and lower SES households. For fish, it should be noted that canned fish such as tuna and sardines were included in the amount consumed, and a previous study found canned fish is a substitute for fresh fish or other expensive meat options. We also saw a reduction in rice with fewer asset ownership, which suggests there might be hierarchy of preferred staples under various food security and/or SES status.

Regarding dietary diversity, overall it remained stable across all age groups, with a median number of food groups consumed per day of four. During La Niña, there is a small but significant increase in DD score by 0.15, while this is reduced for females under La Niña conditions by 0.13. Asset and maternal education have small but significant positive association with DD score.

Finally, with the consumption of gifted foods, we noticed that the odds ratio for consuming gifted foods increased three fold in moderate El Niño, but increased by 20% under weak La Niña. While there was a decrease in gifting by 80% during strong La Niña. Girls were 1.43 [95% CI:1.097-1.860] times likely to consume gifted food items, especially under a moderate El Niño compared to boys. There was seasonality in consumption of gifting – lower at the end of wet season (May and July) and higher in December (which could be related to the Christian holidays). As one would expect, gifting was significantly associated with lower asset ownership and income.

Strengths and Limitations

This study had three major strengths, which included the design, nature of data collection, and analysis/interpretation. This study encompassed a prospective design while examining macro to micro level factors under the same setting and period. Mediating factors such as food prices and food consumption patterns were studied under the same setting and context. Although there are large-scale studies establishing associations among rainfall, food prices, and dietary intake, they are cross-sectional studies from demographic health surveys and national-level data that do not adequately capture the long-term impact at a local level, or provide evidence of association with mediating factors. More importantly, they cannot make inference for the total effect of these fluctuations at the child-level characteristics (such as gender, morbidity). Importantly, Iquitos is an island city, which represents a closed system to study the effects of climate change on nutritional security. The population was studied longitudinally, and thus, the effects of climate, on food prices and dietary fluctuations can be quantified over time.

The prospective study design and intensive follow-up of the children in the community under the MAL-ED framework enabled us to control for all known confounding factors such as morbidity, socioeconomic status, energy intake and breastfeeding status. The data processed under the MAL-ED study had multiple levels of quality control checks. At the field level with the supervisor, at the site level where double data entry enabled the sites to check the skip patterns and illogical answers (negative amount consumed or negative age) automatically, and finally, at the data coordination center, where trained analyst examined data trends. Dietary recalls were conducted by trained community health workers, who recorded extensively, even gifted foods consumed by the child, which further enabled us to examine these practices. Finally, a trained nutritionist conducted extensive recipe analysis and used multiple food composition tables to quantify the nutrient information accurately.

Finally, at the analysis level, parallel analyses were undertaken to examine associations from the main models and interpretations were similar under the different modeling framework. For Aim 2, fixed effects models were run to examine if associations observed under random effects model were consistent, and they were indeed robust. Second, ordinal logistic models were compared with Poisson models fixed and random effects model, which were also consistent. The only models were there was minor disagreement was with tobit and random effects regression models on amounts of food consumed. However, such differences have been observed in another study, and hence both results were presented to the audience. The models did agree on sugar intake (Haines, 1988). Since sugar intake was higher in this population, distributions approximated normality for both types of models. It is possible that lower intakes of yucca and fish might have affected the estimation parameters for the two models, thus resulting in differences in coefficients between the two models.

There are several limitations to this study. There might be potential confounding due to secular trends when comparing different groups of children for Aims 2 & 3 as they are enrolled at various time points. To our knowledge, there have not been changes in existing programs or introduction of social programs or new policy associated with dietary intake in this community. For Aims 2 & 3, energy and nutrients from breast milk are not quantified, and the method used to account for this gap is not optional. Finally, it should be noted that MEI index characterized only one month as moderate La Niña so any effects that were identified under this condition should be researched further with a larger sample size for inference.

Policy Implications and Future Research

There is a growing concern that ENSO patterns will become more frequent and intense under climate change. This study illustrated that ENSO affects food prices through local ecological factors such as river level, and can directly lead to differences in food and nutrient intakes. This has important implications for programs and policies in Peru.

In Peru, there are two nutrition-related national programs that target vulnerable populations. There is a food transfer program called *Vaso De Leche* (VDL) began in 1984 (Alderman and Stifel 2003; Gajate and Inurritegui 2003). VDL distributes milk, milk substitutes, cereals and other packaged foods, depending on the community. Thus far, evaluation has found the VDL has been successful in reaching poor households, however the effect does not translate into improvements in nutritional status beneficiaries' children (Alderman and Stifel 2003; Gajate and Inurritegui 2003). Common criticisms of the program include problems in records management, sporadic distribution and discrepancies in commodity transfers. Another program is a conditional cash transfer program called *Juntos*, which was initiated in 2006 and is modelled after a successful cash transfer program in Mexico that targeted vulnerable groups (Loret de Mola et al. 2014a; OECD 2016). This program gives monthly transfers of 30 USD to mothers of poor households with young children. Early evaluation of this program is promising, as authors found increased utilization of health services for children under five years of age and increased expenditure for certain food groups. These included breads/cereals, butter/oils, vegetables, fruits, sugar, and tubers, but no differences in expenditure were observed for seafood, milk, meat, eggs and cheese. This may differ by region, and until such data are available, no inference can be made as to its importance on the food security in Amazonian Peru.

Because these programs are targeting woman, who are more vulnerable to climate change, and face higher mortality and morbidity under severe weather events, it may offset the gendered effects seen under various ENSO conditions. One major policy implication of this study, is that even under weaker phases of El Niño and La Niña, there were reduced intake of the main staples and meat among children. These existing national program may utilize ENSO conditions as an indicator to heighten program activities or increase frequency of transfers in these conditions (see table 6-3 for nutrition sensitive and specific approaches). Evaluation studies should examine whether these programs are effective by region, especially with varying severity of ENSO phases (Alderman and Stifel 2003; Gajate and Inurritegui 2003; Loret de Mola et al. 2014b; OECD 2016).

Previously, studies in Peru have shown the impact of El Niño on the incidence of diarrhea, and stature among children (Checkley et al. 2000; Ramírez et al. 2013; Danysh et al. 2014). This study identifies nutritional pathways to ameliorate the effects of ENSO on dietary intake. For example, calcium intakes were reduced by 55-95g under La Niña conditions, which is 10-25% of the RNI. Similarly, iron intakes were reduced by 2 grams, which is also 11-27% of the RNI. These sustained reductions in micronutrient intakes over long term exposure to La Niña can negatively affect micronutrient status. In this study, we had limited sample size to study moderate El Niño and moderate La Niña conditions, with no observations for strong El Niño conditions because the birth cohort covered the period of 2010-2014, when these conditions were not observed. This is an important area of research that could be expanded to evaluate dietary intakes under different ENSO severity, particularly how they manifest in the three different socio-ecological zones present in Peru.

Peru is one of a growing numbers of countries that face the double edged sword of under and over nutrition (Uauy and Monteiro 2004; Fraser 2013). We found that consumption of sugar is high in this young population. Although, sugary beverages such as sodas and store bought juices are available in this study area, traditional homemade juices, on average had 20 gram of sugar per 100 ml cup, which may in the longer term affect dental health and increase the risk of childhood obesity. Peru recently signed a bill targeting junk food consumption, which includes food labels, and nutritional education among school age children (Fraser 2013). The shifts in diets and the growing role of these ready-to-eat foods (snacks, store bought sodas or juices) in communities that are facing dual nutrition burden is another important area of research.

Another layer of complexity of the Peruvian food system is that increasingly, Peruvian farmers, especially in the Amazonian regions are promoted to plant the "new cash crops" that accommodate the diet fads of higher income countries. For example, avocados, asparagus, artichokes are grown for export to the United States of America (Keller et al. 2013; FAO 2015). The difference in seasons between North and South America makes Peru a uniquely situated country to grow and export fresh produce. Large-scale changes in crop productivity for export purposes can reduce food sovereignty, especially under climate-related disasters such as severe El Niño and La Niña conditions.

Although, this study is not generalizable to other regions that are affected by ENSO teleconnections, results show that robust and consistent effects of ENSO are estimable at the individual level, and appear to negatively affect girls' dietary intakes and nutrient adequacies. It is important that other low resources settings that are affected by ENSO (Indonesia, Bangladesh, Southern African countries, South China) to explore how this large scale climatic phenomenon affects the nutritional security of its vulnerable population using a gendered lens.

Tables

Table 6-1: Summary of the findings from the three aims

Paper 1	1. ENSO and river discharge of Rio Nanay are associated. 2. MEI index is the best fit for river discharge levels, compared to SOI and ONI index. 3. ENSO severity affects river flows. 4. ENSO severity, river level, and seasonality have a temporal association with regional food price of Loreto, Peru, particularly yucca, eggs, and plantains. 5. Rice prices are the most resistant to environmental conditions suggesting that national policies in place may be offsetting the volatility caused by these factors.
Paper 2	1. Dietary diversity remains consistent across seasons and age groups. Girls tend to have slightly higher dietary diversity than boys. However, during La Niña conditions, girl's DD score is reduced significantly compared to boys but this reduction is very small in magnitude. 2. Under moderate El Niño & La Niña and strong La Niña, there was reduction of meals with fish, grains, plantain, dairy, sugar and rice. In strong La Niña, reduction of rice and grains were 18-20%, and interestingly, there is a higher intake of plantains by 99% suggesting possible substitutions. 3. ENSO differences were observed in the amount of food consumed for fish, rice, and sugar. In particular, there were gender difference by ENSO exposure for yucca, and sugar. 4. There is high consumption of sugar among children in this population ~ up to 20 grams a day per cup of juice. 5. The practice of consuming gifted foods is higher during moderate El Niño and weak La Niña, and is higher among girls compared to boys.
Paper 3	1. Energy intake was significantly lower under moderate El Niño and significantly higher during weak La Niña. Girls consumed less calories than boys even after adjusting for weight and other covariates, particularly under moderate La Niña. 2. Gender differences were seen in animal source protein intake, iron, zinc, calcium intake under various ENSO conditions. 3. NARs of calcium, iron, and zinc were negatively reduced during weak, and strong La Niña. There was increased in NARs of folate observed during strong La Niña. Girls consumed less vitamin B12 and accordingly had lower prevalence of NAR for vitamin B12. 4. Seasonality of intakes was observed for vitamin A, vitamin B12, calcium, Iron, and Protein. NARs of vitamin A, vitamin C, vitamin B12and calcium show seasonal trend while NARs of iron, folate, and zinc don't show apparent seasonal trends. 5. Lower assets and maternal education associated with meat/fish/poultry protein, and lower sanitation. 6. Breastfeeding status was negatively associated with calcium, protein and animal source protein intakes, while positively associated with NARs of vitamin A, calcium, vitamin C and folate.

Table 6-2: Summary of model coefficients of ENSO exposure on meal frequency, amount consumed, macronutrient intakes, micronutrient intakes, and NAR

	Weak El Niño	**Moderate El Niño**	**Weak La Niña**	**Moderate La Niña**	**Strong La Niña**	**Female**	**weak El Niño # Female**	**moderate El Niño # Female**	**weak La Niña # Female**	**moderate La Niña # Female**	**strong La Niña # Female**
Meal frequency (%)											
Fish	0.992	0.755^{+}	0.93	0.995	1.017	0.928	1.045	1.023	1.092	0.63	0.99
Grains	0.974	1.042	1.01	0.827*	0.826*	1.031	0.954	0.97	0.978	1.06	0.91
Meat	1.087	1.122	1.150*	0.782	0.943	1.05	0.91	0.931	0.893	1.14	0.92
Eggs	0.953	0.818	0.96	0.855	0.91	1.1	0.938	0.965	1.085	0.82	0.85
Poultry	1.114^{+}	1.028	1.175*	0.765	0.944	1.061	0.879	0.931	0.866^{+}	0.91	0.91
Plantains	0.963	0.515*	1.190^{+}	1.276	1.992*	1.056	1.113	1.416	0.962	0.304^{+}	0.49*
Rice	0.993	1.109	0.984	0.787^{+}	0.797*	1.062^{+}	0.961	0.924	0.993	1.021	0.93
Dairy	0.93	1.012	1.013	0.878	0.822^{+}	1.151*	1.05	1.108	1.016	0.96	0.99
Yucca	0.824	0.88	0.948	0.717	0.85	0.737*	1.592*	0.917	1.421	0.98	1.39
Sugar	0.958	0.994	1.062	0.582*	0.901	0.996	1.074	1.097	0.890*	1.31	0.87
Amount Consumed (g)											
Yucca	-7.17	-2.712	-4.157	-21.45	-10.17	-13.92*	21.21*	-3.69	16.67^{+}	12.94	21.62
Fish	5.933	-19.22*	-1.368	0.109	-1.593	-2.983	-0.227	4.336	5.852	-3.368	3.99

Rice	-3.787^{+}	0.909	-2.386	-7.041	3.767	-0.0253	-0.171	-6.131	-3.428	5.82	2.767
Sugar	-0.226	-7.464	6.262*	4.009	14.55*	1.355	7.907*	18.04*	-12.36*	11.83	-6.94
Macronutrient intakes											
Energy (kcal)	6.90	-80.76*	85.52*	-2.08	13.20	25.06	20.15	40.6	-16.49	-155.66*	-72.12
Carbohydrate (g)	-1.09	-2.15	3.79*	-2.38	0.12	0.12	3.14	4.31	-1.95	5.21	-0.95
Protein (g)	0.58	0.81	-1.26*	-0.17	-0.4	-0.27	-0.59	-1.89^{+}	0.97^{+}	-0.37	0.5
Animal Source Protein (g)	0.7	0.06	-1.02*	0.76	0.26	-0.44	-0.1	-0.68	1.34*	-1.1	0.32
Meat Fish Poultry Protein (g)	0.91*	0.57	0.25	-0.31	0.55	-0.13	0.1	-0.43	-0.13	-0.7	-0.82
Meat Fish Poultry Iron (mg)	0.06	0.14	0.08	-0.14	0	-0.05	-0.04	-0.14	-0.07	-0.01	-0.1
Micronutrient intakes											
Vitamin A (□g~RE)	-15.26	27.79	-3.36	-33.4	-25.15	-20.62	-20.98	-13.19	-23.45	0.61	-25
Vitamin C (mg)	3.71	20.63*	8.82	38.46*	-19.5	-1.6	-14.84	-16.12	11.5	-1.63	-1.64
Folate (□g)	-1.07	4.04	0.68	-8.26	-2.68	-4.47	-4.43	-10.19	2.41	4.46	0.3
Vitamin B12 (□g)	0.06	0.28	-0.01	-0.11	-0.05	-0.15	-0.2	-0.49	0.07	0.02	0.01
Calcium (mg)	30.56	66.89^{+}	-82.77*	-55.8	-95.54*	-7.84	-27.21	-82.31	49.31	57.41	94.52*
Iron (mg)	0.34	1.29^{+}	-1.07*	-2.10*	-1.97*	-0.15	-0.41	-1.57^{+}	0.11	1.28	1.18
Zinc (mg)	-0.01	0.07	-0.31*	-0.13	-0.14	-0.01	-0.14	-0.32^{+}	0.32*	0.15	0.2
NAR (not truncated at 1.0)											
Vitamin A	-0.19^{+}	-0.22	0.02	-0.62*	-0.26	-0.23	0.11	0.36	-0.05	-0.01	-0.37
Vitamin C	0.99	0.34	1.75	0.09	-2.17^{+}	0.08	-0.32	-0.28	1.11	-0.47	0.37
Calcium	0.05	0.11	-0.19*	-0.15	-0.24*	-0.04	-0.05	-0.15	0.15*	0.21	0.22^{+}
Iron	0.03	0.10^{+}	-0.08*	-0.19*	-0.18*	-0.01	-0.03	-0.12^{+}	0	0.10^{+}	0.11^{+}

Folate	0.01	0.06	0.05	-0.12	0.24*	-0.06	-0.04	-0.08	0.02	0.13	-0.1
Zinc	0	0.01	-0.04*	-0.02	-0.02	0	-0.02	-0.04+	0.04*	0.01	0.02
Vitamin B12	0.11	0.44	-0.03	-0.18	0.07	-0.30+	-0.24	-0.63	0.17	0.09	0.12

Table 6-3: Nutrition sensitive and specific approaches in Peru by ENSO conditions

Nutrition Sensitive	Nutrition Specific
Conditional Cash Transfer Program (*Juntos*), target girls & using ENSO as an indicator for additional transfers.	Targeted Glass of Milk program (*Vaso de Leche)*
Explore potential 'ENSO' credit or ENSO related food price subsidies.	Red Cross Peru, targeted supply of animal source foods and/or iron, zinc and calcium rich foods.

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Chapter 7 Appendix

24 Hour Food Recall Form from the MAL-ED study

FRQ/RA/FRQ/v5/23Aug11 PAGE NO. ☐ of ☐

24 HOUR FOOD RECALL QUESTIONNAIRE (FRQ)

1. Participant ID: ☐☐☐☐☐☐☐☐ **2. Date (DD/MMM/YY):** ☐☐/☐☐☐/☐☐ **3. Fieldworker ID:** ☐☐☐

Instructions: Options for *Home*: Food consumed at home=1, Elsewhere = 0; Options for *R/C: Raw or Cooked*: Raw =1; Cooked = 2.

					Recipe		Food Item			Food Served		Food Leftover	
4	5	6	7	8	9	10	11	12	13	14	15	16	17
Line#	**Food #**	**Meal**	**Home**	**Time**	**Description**	**Code**	**Description**	**Code**	**R/C**	**Portion Size Description**	**Amt (g)**	**Portion Size Description**	**Amt (g)**
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA	(4 digits)	☐ NA	(6 digits)		☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA		☐ NA			☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA		☐ NA			☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA		☐ NA			☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA		☐ NA 73			☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA

FRQ/RA/FRQ/v5/23Aug11

PAGE NO. ☐ **of** ☐

MAL-ED

Instructions: Options for *Home:* Food consumed at home=1, Elsewhere = 0; Options for *R/C: Raw or Cooked*: Raw =1; Cooked = 2.

					Recipe		Food Item			Food Served		Food Leftover	
4	5	6	7	8	9	10	11	12	13	14	15	16	17
Line#	**Food #**	**Meal**	**Home**	**Time**	**Description**	**Code**	**Description**	**Code**	**R/C**	**Portion Size Description**	**Amt (g)**	**Portion Size Description**	**Amt (g)**
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA	(4 digits)	☐ NA	(6 digits)		☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA		☐ NA			☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA		☐ NA			☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA		☐ NA			☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA
☐☐	☐☐	☐☐	☐	☐☐:☐☐	☐ NA		☐ NA			☐ NA	☐ NA	☐ 0 .0 ☐ NA	☐ 0.0 ☐ NA

18. How many times was the child nursed during the daytime: ☐☐

9. How many times was the child nursed during the nighttime: ☐☐

20. Total times nursed: ☐☐

21. **Comments**:

22. Is this form collected for secondary recall? ☐☐ **[00=NO; 01=YES]**

Food Recipe Form from the MAL-ED study

FRS/RA/v1.2/09May12

MAL-ED

1. Participant ID: ☐☐☐☐☐☐☐☐
2. Date (DD/MMM/YY): ☐☐ / ☐☐☐ / ☐☐
3. Fieldworker ID: ☐☐☐
4. Recipe Name: ______________________________ 5.Recipe Code: ☐☐☐☐☐☐

24 HOUR RECALL FORM PART 2 (FRS)

Instructions:

6. line #	7. Ingredient	8.Code	9.Amount	10.Weight (g)	11.Remarks
1		(6 digits)		☐☐☐☐☐	
2		(6 digits)		☐☐☐☐☐	
3		(6 digits)		☐☐☐☐☐	
4		(6 digits)		☐☐☐☐☐	
5		(6 digits)		☐☐☐☐☐	
6		(6 digits)		☐☐☐☐☐	
7		(6 digits)		☐☐☐☐☐	
8		(6 digits)		☐☐☐☐☐	
9		(6 digits)		☐☐☐☐☐	
10		(6 digits)		☐☐☐☐☐	
11		(6 digits)		☐☐☐☐☐	
12		(6 digits)		☐☐☐☐☐	
13		(6 digits)		☐☐☐☐☐	
14		(6 digits)		☐☐☐☐☐	

12.Cooking Method Notes: ______________________________

FRS Page 1 of 1

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Nutritional and Morbidity surveillance questionnaire from the MAL-ED study

SAF/SAR/v2.3/31MAY10

Child ID: □□□□□□□□ MMM/YY: □□□/□□

MAL-ED

SURVEILLANCE ASSESSMENT FORM (SAF)

01	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
02	Visit today?																															
03	# times																															
04	Field researcher																															
	Current health status. Ask about all days since last visit (Yes=1, No=0, NA). [1]Choices for ACTIVITY LEVEL (normal=0, sleepy=1, difficult to awaken=2). [2]Choices for ORAL INTAKE (normal or more=0, less than normal=1). [3]Choices for ANTIBIOTICS (Penicillin=1; Cephalosporins=2; Sulfonamides=3; Macrolides=4; Tetracyclines=5; Fluoroquinolones=6; Unknown=7; Metronidazole=8; Other=9).																															
05	Illness?																															
06	Activity level?[1]																															
07	Oral intake?[2]																															
08	Vomiting?																															
09	Ear pain / pulling?																															
10	Antibiotic use?																															
11	Antibiotic type[3]																															
	Gastrointestinal illness. Ask about all days since last visit (Yes=1, No=0, NA). [4]Choices for DEHYDRATED (None=0, Some=1, Severe=2).																															
12	Diarrhea?																															
13	# loose stools?																															
14	Blood in stool?																															
15	Dehydrated?[4]																															
16	ORT administered?																															
17	Sample collected?																															
	Respiratory illness. Ask about all days since last visit. If answer to question 18 or 19 is YES in the past 24 hours, look for chest indrawing and record respiratory rate (breaths/minute) twice.																															
18	Cough?																															
19	Short of breath?																															
20	Indrawing?																															
21	Respiratory rate 1																															
22	Respiratory rate 2																															
23	ALRI?																															
	Other information. Ask about fever on all days since last visit (Yes=1, No=0, NA). If answer to question 24 is YES in the past 24 hours, record temperature (XX.X °C).																															
24	Fever?																															
25	Temperature °C																															
26	Referral made?																															
27	Nursing notes?																															

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SAF Page 1

SAF/SAR/v2.3/31MAY10

Child ID: □□□□□□□□ MMM/YY: □□□/□□

MAL-ED

	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	What liquids are the child consuming? (ask about past 24 hours and fill in column corresponding to yesterday's date) (Yes=1, No=0, NA)																															
28	Breast milk																															
29	# times during night																															
30	# times during day																															
31	Infant formula																															
32	# times during night																															
33	# times during day																															
34	Animal milk - Tinned, powdered, or fresh																															
35	# times during night																															
36	# times during day																															
37	Plain water																															
38	Tea, coffee, local examples																															
39	Fruit juices																															
40	Other liquids																															
	What solid foods are the child consuming? (ask about past 24 hours and fill in column corresponding to yesterday's date) (Yes=1, No=0, NA)																															
41	Semi-solid, mashed or solid foods? If NO, then stop.																															
42	Porridges, breads, other foods/drinks made from wheat, oat, barley, soy?																															
43	Rice?																															
44	White potatoes, white yams, manioc, other roots?																															
45	Peanuts, spreads with peanuts?																															
46	Beans, peas, lentils?																															
47	Bananas?																															
48	Yogurt, keifer?																															
49	Onions, leeks, shallots, garlic?																															
50	Fermented foods or drinks?																															
51	Supervisor check (initial)																															

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SAF Page 2

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EDUCATION AND TRAINING

2012-16 **PhD, Human Nutrition, Department of International Health**

Certificate in Public Health Economics

Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

Dissertation: "Effects of El Niño Southern Oscillation and Seasonality on Food Prices, Dietary and Nutrient Intake: A Case Study in Iquitos, Peru"

Adviser: Dr. Laura Caulfield

Defended: November 14, 2016

2007-09 **MHS in International Health, Global Disease and Epidemiology Control.**

Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

Master's Essay: "Community Based Health Intervention: Case Studies on community health fund and capacity building of community health workers & oversight committee in Rural Andhra Pradesh, India"

Adviser: Dr. William Pan

2007 **BS, Environmental Science**

University of Maryland, Baltimore County.

Adviser: Dr. Christopher Swan

PROFESSIONAL EXPERIENCE

2016-current **Management Systems International, Washington DC**

Research Analyst, on the NOURISH project in Cambodia (https://cambodia.savethechildren.net/news/usaidwashington-visit-nourish-project)

Responsibilities**:** Conducted survey data analysis & data quality checks on baseline data on anthropometry, food frequency

	questionnaire, water and sanitation indicators, and socio economics status. Conducted Principal Component Analysis to establish index indicators for wealth. Created sampling weights for the surveyed participants. Produced data visualization and summary statistics for the USAID baseline report. Assisted in other relevant data analysis and writing tasks for the baseline report.
2009-current	**Fogarty International Center, National Institute of Health, Bethesda, MD**–Research Associate on Malnutrition-Enteric Disease (MAL-ED) Global Child Health Project (http://mal-ed.fnih.org/) Responsibilities**:** Conducted longitudinal data analysis & quality assurance on nutritional aspects (including dietary recall, food frequency questionnaire, anthropometry) and vaccine response components of the project. Conducted analysis on diarrheal disease outcomes and risk factors from a community based project in rural Pakistan & MALED study. Developed protocols and questionnaires for an environmental epidemiology pilot study in Fortaleza, Brazil, and conducted site visits to India and Nepal MAL-ED sites. Experience analyzing large data sets (~1 million observations) of nutritional surveillance for the MAL-ED project.
Aug 2015-Feb 2016	**Global Obesity Prevention Center, Baltimore MD** Research Analyst, Dr. Bruce Lee Responsibilities: Conceptualize food supply models for the HERMES project and collect data for evaluating food supply chains using discrete event modeling.
2013	**Global Health Established Field Placement, Johns Hopkins Bloomberg School of Public Health, Iquitos, PERU** Research Assistant, Dr. Margaret Kosek Responsibilities: Create, develop, analyze and validate a new food security tool for Iquitos, Peru for infants enrolled in the Malnutrition-Enteric Disease Peru site.
2012-13	**Johns Hopkins Bloomberg School of Public Health, Baltimore, MD.** Research Assistant, Dr. Laura Caulfield Responsibilities: Review, analyze and perform quality control on 24-hour recall dietary recipes from infants enrolled in the Malnutrition-Enteric Disease Nepal site
2011-2012	**University of Venda- South Africa, SOUTH AFRICA** Research Analyst on Malnutrition-Enteric Disease (MAL-ED) Responsibilities: Implemented quality control for nutritional

surveillance and cognitive activities, trained project staff on data management and basic analysis using STATA, conducted anthropometry and edema training with field workers, developed protocols for edema and breast milk collection, and performed monthly data analysis of nutritional surveillance data.

2008-2009 **Society for Elimination of Rural Poverty, Andhra Pradesh, INDIA**

Health & Nutrition Intern
Responsibilities: Process documentation of Health & Nutrition interventions that aims at reducing poverty due to ill health in rural areas of Andhra Pradesh, developed protocol for data management of case studies, lessons learned and success stories, analyzed and published reports on two case studies on capacity building of community health workers and community based health insurance in rural AP, assisted in survey tool development and impact evaluation of the Health & Nutrition program, and proposals and collaborated partnerships to integrate Home Based Neonatal Care (Gadchiroli model) into Andhra Pradesh rural health care system.

2003-2007 **University of Maryland, Baltimore County (Baltimore, MD)**
Research Assistant in Swan Aquatic Ecology Lab.
Responsibilities: Conducted independent study on the relationship between biodiversity of invasive species, and its effects on soil micro-organisms.

2006 **Western Ecology Division Environmental Protection Agency (Corvallis, OR)**
Research Intern
Responsibilities: Examined the phytotoxicity of carbon nanotubes on five species of plants recommended by EPA for the seedling emergence test. Investigated the effects of nanotubes on agricultural crops.

2005 **Insect Entomology Research**, **University of Maryland, College Park, MD**
Research Intern
Responsibilities: Studied Spatial Subsidy of an Intraguild Predator: Consequences for Top-down and Bottom-Up Impacts Insect Herbivores.

PROFESSIONAL ACTIVITIES
American Society of Nutrition 2012-Current
Ecological Society of America 2005-2007

HONORS AND AWARDS
– Abell Award in Urban Policy for Baltimore City – “Litter-Free Baltimore:

- A trash collection policy framework based on spatial analysis and social media", 2016
- Environment, Energy, Sustainability and Health Initiative Fellow, 2015-2016.
- Finalist for Emerging Leaders in Nutrition Science Poster Competition at American Society of Nutrition, Boston 2015 "Mixed methods approach to characterize longitudinal food insecurity and coping strategies in the Peruvian Amazon"
- Richard Hall Award, 2015.
- IGERT: Water, Climate, Health Fellowship for Graduate Training, 2013-2015.
- Nutritional Epidemiology Poster competition award – 1st place at Experimental Biology, San Diego 2014 "High-resolution longitudinal analysis to evaluate the timing, duration and dynamics of exclusive breastfeeding in the Peruvian Amazon"
- Harry J. Prebluda Fellowship in Nutritional Biochemistry, 2014.
- Departmental Travel Award to Experimental Biology, 2014.
- Global Health Established Field Placement: Summer 2013 Grant recipient.
- Meyerhoff Scholar 2003-2007.
- EPA undergraduate GRO (Greater Research Opportunity) fellow 2005-2007.
- Undergraduate Research Award 2007.
- Research Experience for Undergraduate 2005.

TEACHING EXPERIENCE

Teaching Assistant to Graduate level course: Nutrition Epidemiology Spring & Summer 2016.
Teaching Assistant to Graduate level course: Assessment of Nutritional Status Fall 2015.
Teaching Assistant to Graduate level course: Nutrition and Life Stages Fall 2015

LANGUAGES

English—Fluency, both written and oral
Tamil—Fluency, both written and oral
Spanish —Basic

SKILLS

Proficient in statistical analysis and software (STATA)
Basic use of R, SPSS, and TreeAge

RELEVANT COURSEWORK

Nutrition Epidemiology, International Nutrition, Nutrition & Life Stages, Assessment of Nutritional Status, Biostatistics, Time Series Analysis, Longitudinal Data Analysis, Econometrics, Economic Evaluation, and Psychosocial Statistics (Principal Component Analysis & Exploratory Factor Analysis).

EDITORIAL DUTIES

Reviewer: *Journal of Nutrition (2014-present)*
Reviewer: *Ecology of Food and Nutrition (2014-present)*

REFERENCES

1. Laura E. Caulfield, Professor in the Program of Human Nutrition at Johns Hopkins School of Public Health. Contact information: lcaulfi1@jhu.edu and 410-955-2786.

2. Jessica Seidman, Project Manager of the MAL-ED project at Fogarty international Center at National Institutes of Health. Contact information: seidmanj@mail.nih.gov and 301-402-5753.

3. Benjamin Zaitchik, Professor in the Department of Earth and Planetary Sciences in Johns Hopkins University. Contact information: zaitchik@jhu.edu and 410-516-4223.

PUBLICATIONS

1. **Ambikapathi R,** Kosek MN, Lee GO, Mahopo C, Patil CL, Maciel BL, et al. How multiple episodes of exclusive breastfeeding impact estimates of exclusive breastfeeding duration: report from the eight-site MAL-ED birth cohort study. Maternal and Child Nutrition. 2016 Aug 8;1–17.
2. **Ambikapathi R,** Rothstein JD, Peñataro Yori P, Olortegui MP, Lee GO, Kosek M, et al. Purchase of Sweet and Sugary Beverages and Type of Meat is Indicative of Food Security Status Using a Newly Developed and Validated Tool in the Peruvian Amazon.
3. Applegate JA, Walker CLF, **Ambikapathi R,** Black RE. Systematic review of probiotics for the treatment of community-acquired acute diarrhea in children. BMC Public Health. 2013 Sep 17;13(Suppl 3):S16.
4. Cañas JE, Long M, Nations S, Vadan R, Dai L, Luo M, **Ambikapathi R**, et al. Effects of functionalized and nonfunctionalized single-walled carbon nanotubes on root elongation of select crop species. Environ Toxicol Chem. 2008 Sep;27(9):1922–31.
5. Caulfield LE, Bose A, Chandyo RK, Nesamvuni C, de Moraes ML, Turab A, **Ambikapathi R**, et al. Infant feeding practices, dietary adequacy, and micronutrient status measures in the MAL-ED study. Clinical Infectious Diseases. 2014 Nov;59 Suppl 4(suppl 4):S248–54.
6. Haidari LA, Brown ST, Ferguson M, Bancroft E, Spiker M, Wilcox A, **Ambikapathi R** et al. The economic and operational value of using drones to transport vaccines. Vaccine. 2016 Jul 25;34(34):4062–7.
7. Hoest C, Seidman JC, Pan W, **Ambikapathi R**, Kang G, Kosek M, et al. Evaluating associations between vaccine response and malnutrition, gut function, and enteric infections in the MAL-ED cohort study: methods and challenges. Clinical Infectious Diseases. 2014 Nov 1;59 Suppl 4:S273–9.
8. Lee G, Paredes Olortegui M, Rengifo Pinedo S, **Ambikapathi R**, Peñataro Yori P, Kosek M, et al. Infant feeding practices in the Peruvian Amazon: implications for programs to improve feeding. Rev Panam Salud Publica. 2014 Sep;36(3):150–7.
9. **MAL-ED Network Investigators**. The MAL-ED study: a multinational and multidisciplinary approach to understand the relationship between enteric pathogens,

malnutrition, gut physiology, physical growth, cognitive development, and immune responses in infants and children up to 2 years of age in resource-poor environments. Clinical Infectious Diseases. 2014 Nov 1;59 Suppl 4:S193–S206.
10. Patil CL, Turab A, **Ambikapathi R**, Nesamvuni C, Chandyo RK, Bose A, et al. Early interruption of exclusive breastfeeding: results from the eight-country MAL-ED study. J Health Popul Nutr. 2015 Jan 1;34(1):10–0.
11. Wimp GM, Murphy SM, Lewis D, Douglas MR, **Ambikapathi R**, Van-Tull L, et al. Predator hunting mode influences patterns of prey use from grazing and epigeic food webs. Oecologia. 2013 Feb;171(2):505–15.